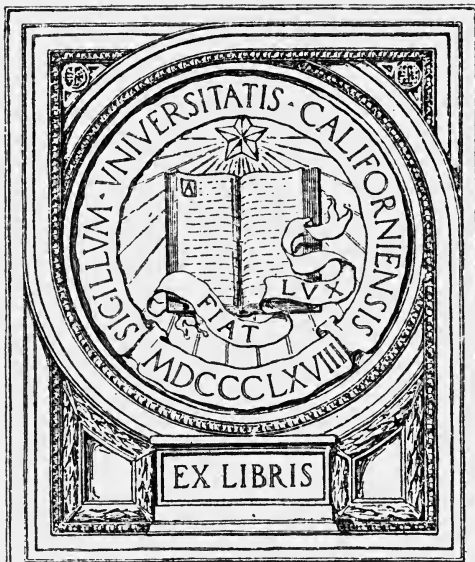

SIGILLVM · VNIVERSITATIS · CALIFORNIENSIS
FIAT LVX
MDCCCLXVIII
EX LIBRIS

WESTERN AUSTRALIA.

DEPARTMENT OF
AGRICULTURE AND INDUSTRIES.
(IRRIGATION DIVISION).

PUBLICATION NO. 41.

HANDBOOK OF IRRIGATION AND DRAINAGE

BY

A. H. SCOTT,
IRRIGATION EXPERT.

PRICE - - - 1s.

PERTH:
BY AUTHORITY: FRED. WM. SIMPSON, GOVERNMENT PRINTER.
1913.

WESTERN AUSTRALIA.

DEPARTMENT OF

AGRICULTURE AND INDUSTRIES.

(IRRIGATION DIVISION).

PUBLICATION NO. 41.

HANDBOOK OF IRRIGATION AND DRAINAGE

BY

A. H. SCOTT,

IRRIGATION EXPERT.

PRICE - 1s.

PERTH:

BY AUTHORITY: FRED. WM. SIMPSON, GOVERNMENT PRINTER.

1913.

Fig. 1.—Brunswick State Farm—Lucerne and Maize under Irrigation—Frontispiece.

IRRIGATION AND DRAINAGE.

By A. H. SCOTT,
Irrigation Expert.

INTRODUCTION.

Irrigation is, to an extent, a scientific undertaking, and for this reason is probably viewed by many as a question of such profundity as to be impracticable without the direct aid, on the spot, of a scientifically trained man. This is not, however, the case, for, without going into the more abstruse features of hydraulics, simple irrigation methods can be employed by the average enlightened farmer, by following such advice as will be found in these pages, wherein I have attempted to describe, in simple language, most of the problems which surround an undertaking of the nature likely to be employed in this State, the data and deductions being the result of experience gained in the many countries visited by the writer.

In the production of a pamphlet likely to be of the utmost utility for our conditions, I have considered it of advantage to touch upon, and at times briefly quote from, recognised authorities in other parts of the world, in order to make the work as intelligible as possible.

Bulletin 373, "The Irrigation of Lucerne," by Dr. S. Fortier (Chief of Irrigation Investigations, United States Department of Agriculture), is reprinted, especially because of the interest which has been shown in Western Australia in Lucerne growing, which makes it advisable that growers, present and prospective, shall be placed in possession of the latest practical information and advice regarding the best methods of irrigated culture and the utilisation of water applied to agriculture. The reprinted work, with its numerous illustrations, will be found generally adaptable to the conditions ruling in many portions of this State.

The whole question of irrigation must be viewed from the standpoint of "Will it pay?" Some people, carried away with the possibilities of irrigation, lose sight of the all-important financial end of the question, and make extensive investment in apparatus which is unnecessary or unsuited to the work to be done. Others, from ill-advised ideas of economy, endeavour to irrigate without properly laying out their land, and spend on labour alone many times the cost of a suitable scheme. To speak intelligently about irrigation we must know the cost and the value, not only of the undertaking as a whole, but of the individual parts thereof.

These are subjects of primary importance. The actual cash outlay necessary for operation is often considered as the cost of irrigation, but allowance has to be made for interest or depreciation on the investment in the irrigation plant.

Irrigation is the most scientific form of farming, and the problem of whether to irrigate or not has occupied a large share of attention during the past few years.

The possibilities of irrigation here have, as yet, scarcely been touched. It is true we do not possess many large running streams which can be drawn upon during the summer months, but against this there are large areas of country

Fig. 2.—Irrigation Plant, Brunswick State Farm.

where underground supplies can be tapped at moderate depths, while many localities possess suitable sites where the winter floods can be conserved by means of reservoirs or dams.

Australia has been in the past the land of great estates, but where water for irrigation is available in the agricultural and horticultural districts it should become a land of small holdings.

Irrigation increases the value of land, and produces remarkable financial gains, provided the work is skilfully performed and that good drainage—either natural or artificial—supplements it. Of course, there are moist lands where certain crops may be produced with the utmost success without the aid of water from a ditch, but this is merely natural sub-irrigation, a matter wholly apart from the annual rainfall.

It would be well for the intelligent farmer to make a thorough study of the history and methods of irrigation as early as possible. He may go along very well in his home by following the practice and advice of his neighbours, but he will be more successful if he studies the science of irrigation in relation to soils, crops, methods, etc., and particularly with reference to his own land, for, of course, success in irrigating depends, to a large extent, as already stated, upon the skill with which it is done.

At the Brunswick State Farm (Fig. 1) the Department of Argiculture and Industries has installed an irrigation plant capable of pumping 70,000 gallons per hour (Fig. 2). This work is intended as an object lesson in the economical distribution of water and further, to show, by its practical results, the increase in crops per acre which may be obtained by the proper application of water, through the dry season, both on poor and rich land. The furrow and border flooding systems can be seen in operation. Those who have any intention of irrigating should visit this farm. Every opportunity will be afforded to visitors to investigate thoroughly and criticise the methods employed. To view practical results must be of far greater value and assistance than could be derived by any theoretical knowledge.

The value of fruit and cereal crops of California under irrigation long ago out-stripped that State's product of gold in its palmiest days, and similar results may be attained here by the adoption of the same course.

Creeks and springs in California, Arizona, and Colorado which possessed little value 20 or 25 years ago and which were then permitted to flow to waste are now eagerly sought after, and yearly increase in value.

At Renmark, South Australia, 5,000 acres are under irrigation, carrying a population of over 1,000 people, turning out produce of over £135,000 in value in fresh and dried fruits.

The South-Western districts of this State, with the many permanent streams and watercourses, offer abundant opportunity for the successful use of irrigation, and when this fact is once appreciated, as before long it surely will be, many a block now untilled will become of the greatest value for the growth of summer fodder. In the application of irrigation and suitable manures to the land in this portion of the State lies the solution of the successful carrying on of dairying.

At present farmers who are irrigating are co-operating with the Department by keeping careful records of their activities. A form on which this information can be supplied is forwarded annually to every irrigator in this State; by this means it is known if the farmer's irrigation project is payable, what he is growing, the source of water supply, and other valuable data, and it is thus possible to determine what can be best grown, under irrigation, in the different districts. It shows, at the same time, that an interest is being taken in the farmer and his work, and that further advice is to be obtained should it be required.

Mr. Elwood Mead, late Chief of Irrigation Investigations, U.S.A., and now Chairman State Rivers and Water Supply Commission, Victoria, in one of his reports states:—

"Ultimate success in irrigation development depends on the way farms are irrigated. In American irrigation practice this particular branch of the subject has been much neglected.

"Hydraulic engineers have assisted associations and corporations in the designing and construction of reservoirs, dams, and main canals, but Western farmers have received little help in devising measures for the proper use of water. The art of irrigation in this country has become, in consequence, somewhat one-sided, much more consideration having been given to the diversion and conveyance of water than to its distribution and application to the soil. Reservoirs and canals are but means to accomplish a purpose, and that purpose is to increase the products of the soil. The time is coming when the most important problem connected with irrigation will be the needs of the plant as regards moisture, and not, as at present, those of storage and conveyance.

"If all-round progress is to be made it is imperative that the same degree of skill and intelligence be used in spreading water over the field as is now exercised in bringing water to the farmer's head gate.

"Too much credit cannot well be given to the comparatively small number of farmers who have devised the present methods of using water. In the majority of cases these methods are probably best suited to the particular farm for which they were designed, but, at the same time, they may be wholly unfitted for the neighbouring farm. In this connection wise selections are the exception, and not the rule. Farmers imitate the methods of a few enterprising leaders, without much thought as to the effects of varying local conditions. It has been shown, for example, that the proper way to apply water to a field will depend on the texture of the soil, the nature of the crop, and other local conditions. In view of this, it is evident that all the farms in a district should not be irrigated in the same way. Considerable experience and a high order of intelligence are necessary to make the best possible use of water for irrigation. In deciding on the best direction to run field ditches or how to prepare the surface, the example of a neighbour, or the usual practise of a community is not sufficient reason for adopting a particular system.

"The only safe plan is to examine closely the conditions of one's farm, and then out of many methods, to choose the one which will suit best. This, however, involves an intimate knowledge of different methods."

The above extract confirms my own views entirely and demonstrates that the system we have been following in this State of giving practical instructions to the farmer who is using water for irrigation is sound. Lack of experience in irrigation practice is the greatest factor we have to contend against, it being absolutely necessary, in the majority of cases, to visit the farmer and his farm periodically if the undertaking is to be ultimately successful.

PREPARING LAND FOR IRRIGATION.

The first matters for consideration before undertaking any irrigation scheme are:—

(1.) The quantity and quality of the water supply.

(2.) The suitability of the land for irrigation.

(3.) The number of acres to be placed under irrigation, and the crops desired to be grown.

(4.) The vertical distance from ground level to water level, and lateral distance from source of supply to the point where the water is to be discharged (if power is required).

Thoroughly discuss the subject with a qualified man and arrange a visit to the farm if possible. The next step is to determine the best way of laying out the land. Judging the true slope of the ground by the eye is a very risky undertaking, for even the most experienced are often deceived.

Every irrigation scheme should be laid out with a surveyor's level and a contour plan made of the whole area.

LEVELLING THE LAND.

The Buck-scraper (Fig. 3), Fresno Scoop, Wheel-grader (Figs. 4 and 5), and Slicker or Smoother (Figs. 6 and 7) are the implements most commonly used for levelling land for irrigation. The Buck-scraper and Slicker can be constructed

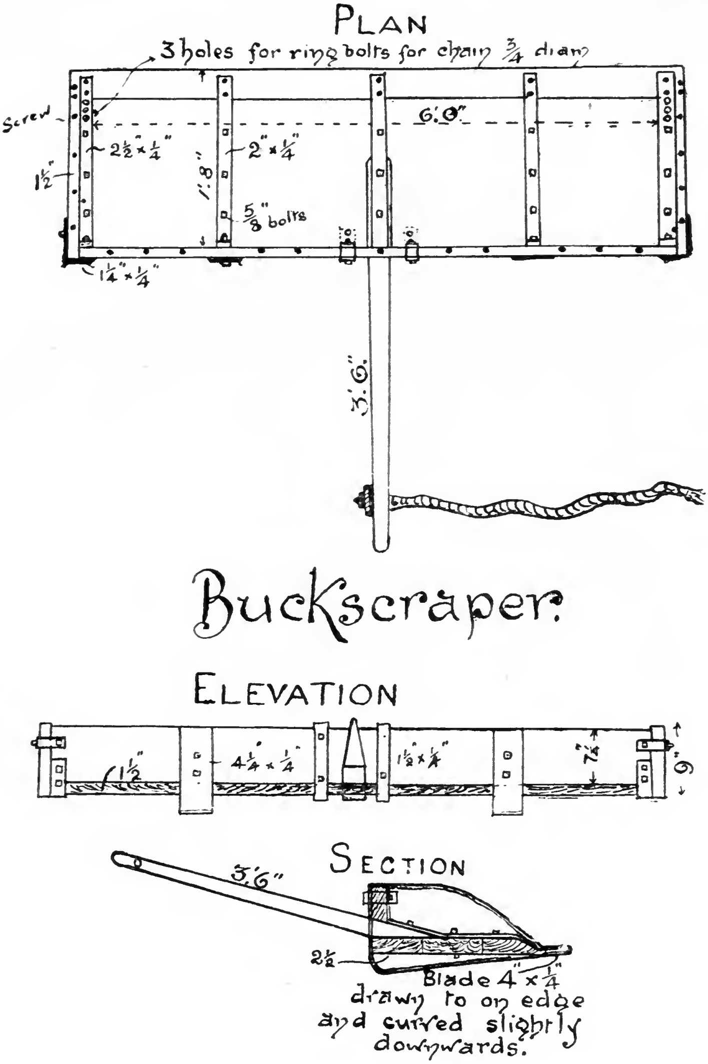


Fig. 3.—Diagram of Buckscraper.

by any blacksmith at a cost of from £10 to £12 for the two. The Fresno Scoop as a rule, is made in several sizes, and may be obtained from agricultural machinery firms at a cost of £7 to £9. It is easy to handle, and can be used for forming

roads, building levees, digging ditches, or doing any work which requires the moving of dirt.

Fig. 4.—Ditcher and Grader.

The levelling of the land is a work involving more time and expense than anything else connected with the starting of a new place.

The Buck-scraper is a most effective implement for moving loose or sandy earth where the haul is short, and in every case four good horses abreast are necessary (Fig. 8). It is strong, portable, and has a wide range of use. It loads quickly and loses but little in transportation. After the load is dumped the team may be turned readily, and, when empty, the scraper is drawn with sagging traces. Its simplicity and cheapness also commend it to the farmer and contractor (Figs. 9, 10, 11). It has, however, the following disadvantages:—

(1.) Skill in handling is necessary for rapid work, and experienced help is usually difficult to find.

(2.) The labourers object to the constant lifting in loading and dumping.

(3.) Roots and rubbish will catch on the blade of the scraper, making it impossible to load until removed.

Much labour and inconvenience in irrigating can be avoided by making the levelling as perfect as possible. Fig. 12 shows a perfectly graded tennis court flooded. Before it is considered finished, water is sometimes turned upon the field and its surface practically tested for uneven places, and additional grading done afterwards where shown to be desirable. An ideal field is one which slopes gently and uniformly.

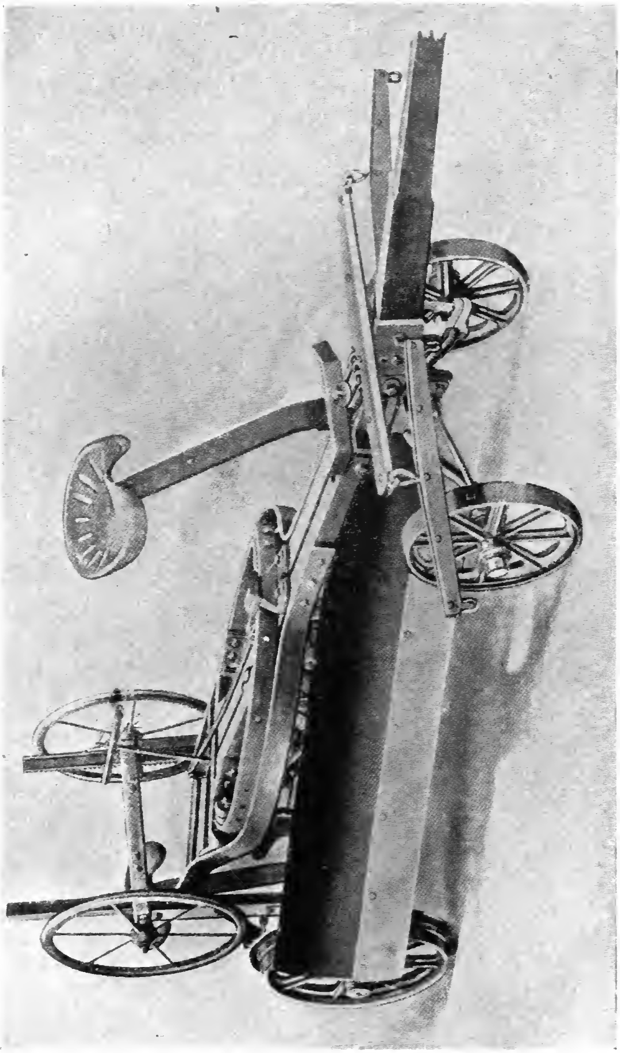


Fig. 5.—Four-wheeled Grader.

If the soil is shallow and the value of the land is high the upper layer of soil is removed from a strip about 50 or 60 feet wide, and put in piles near by, after which the lower and poor soil is scraped into the depression. The soil first moved together with the upper soil on both sides is then scraped into the excavation and the underlying poor soil is taken to the low places. The better soil which was scraped into the excavation is then evenly distributed over the surface of the poorer soil exposed.

The injurious effects of attempting to spread water over uneven surfaces are soon apparent. Water settles in the low ground water-logging the soil, and drowning the plant life, while an insufficient supply reaches the higher elevation leaving the crops to turn up. When once the surface is properly graded one man can apply the water to every part of a field with greater rapidity and effectiveness than three or four men can irrigate a like area where the slopes are rough and uneven.

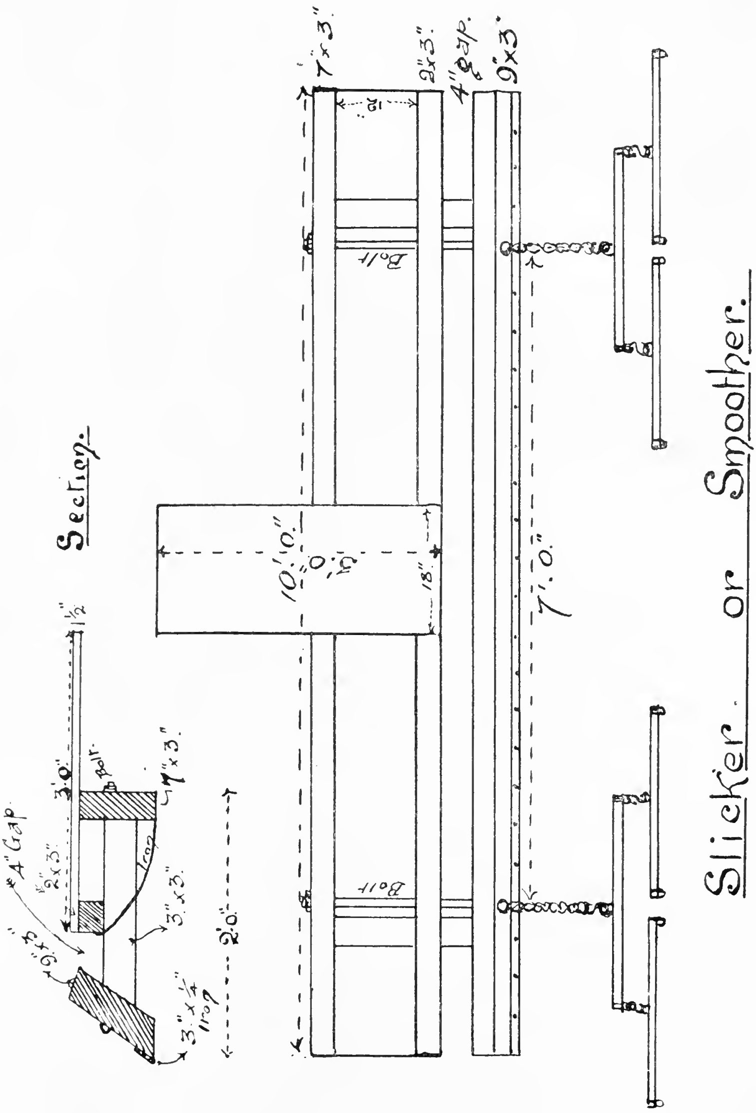


Fig. 6.—Diagram of Slicker or Smoother.

Too much stress cannot be put upon the importance of laying out the field ditches before grading. The average fall for field laterals should vary from 1 inch to 1½ inches per chain, depending upon the nature of the soil and general conditions. In laying out a system of ditches or laterals to serve a farm, it is important for the future saving of money and labour to run the main ditch along the highest portion of the farm, in order to command the greatest irrigable area. This

sounds so reasonable it seems scarcely necessary to mention it, yet, unfortunately, many an inexperienced irrigator may see in the area of his farm certain broad fields of gently sloping grounds so pleasing to the eye that his very first impulse is to run a lateral from the nearest point to the choicest piece of ground, altogether overlooking—or not duly considering—the worth of less favourable ground, thereby leaving pieces of excellent land high and dry above the main ditch. When the time comes in which he finds it will be profitable to expand the cultivated portions of his farm and to put every square foot under irrigation, then, instead of supplying the fields he wishes to water from his main ditch, he discovers the necessity of going to his original source of supply and building another ditch, often parallel-

Fig. 7.—Slicker at Work on River Flat in the Wellington District.

ing his main laterals, but on higher grounds. If the original laterals had been properly located, instead of being obliged to build a new main ditch large enough to carry a sufficient supply for his whole farm, he could simply have extended sub-laterals from the main laterals already commanding his farm and proceeded to reclaim whatever part he wished of the unbroken area.

The cost of preparing land for irrigation varies with the condition of the ground, the class of irrigation, and the price of labour. An approximate estimate could be placed at, say, £5 per acre. In this State the cost has ranged from £1 to £8 per acre.

The grading of land for lucerne in this State has been mostly confined to the Border method. On the Brunswick State Farm the borders or lands measure from 15 feet to 66 feet wide by from 165 to 400 feet long. Each levee or ridge has a base from 3 to 4 feet wide and is 6 inches high when newly made, but settles to about 4 inches before the end of the season. The location of each border was marked out with the plough. Sufficient earth to form the retaining banks or levees was obtained by ploughing and reploughing the bank sites, the open furrows left on each side were filled by running the slicker or Buck-scraper at an angle alongside. Fig. 13

shows a photograph of a well laid out lucerne patch on the Brunswick State Farm. Note the regulating of the stream by the sluice boxes through bank.

The old adage "Work once well done is twice done" can be applied with no stronger significance than in preparing land for irrigation.

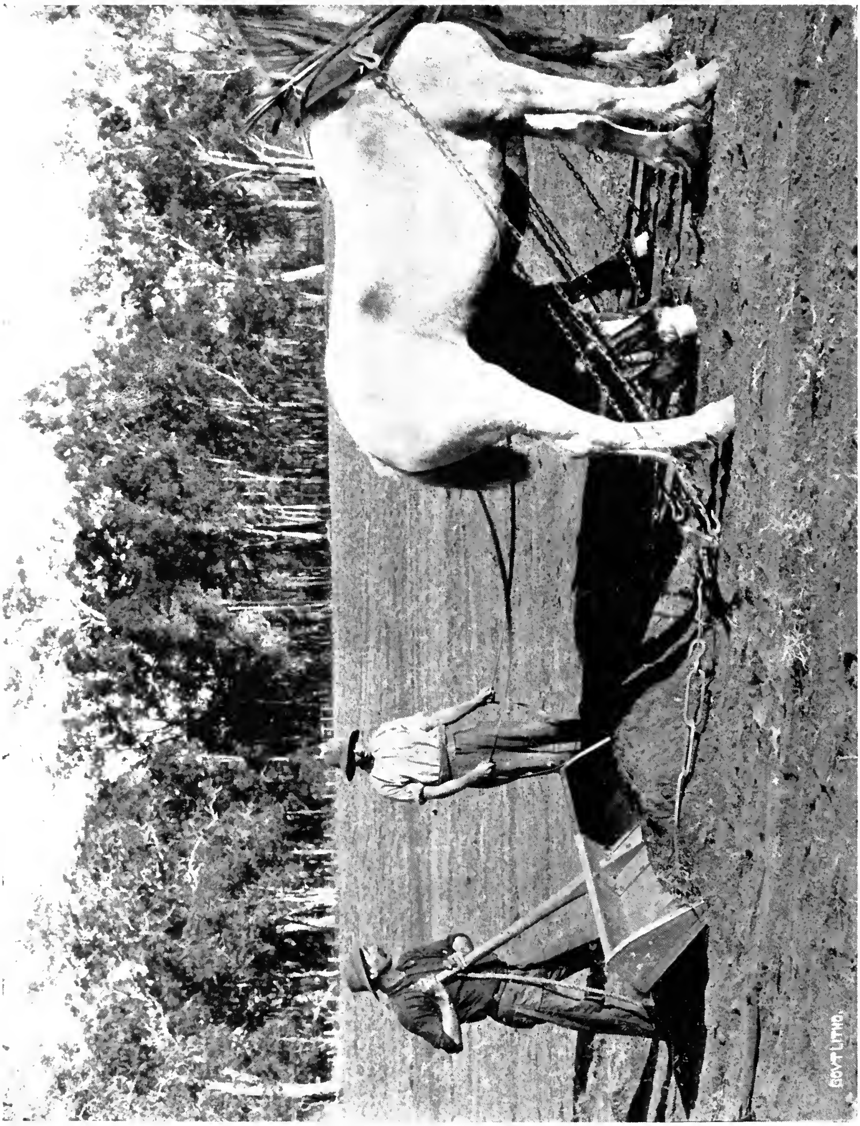


Fig. 8.—Four-horse 6ft. 6in. Buckscraper grading land, S.W. District.

SANDY SOILS.

In this State we have large areas of poor sandy soils which, so far, are unproductive. These lands are poor in plant food, and retain so little moisture that all attempts to farm them have failed. Manure alone is of little use, as there is not water enough in the soil to make the plant food available. Water alone, in many cases, has produced good results, but with the application of both splendid returns

have been shown. With certain crops the irrigation of these sandy lands can be made profitable, but only if water can be applied at a low cost.

Fig. 9.—The Author's teams at work constructing a main channel with Buckscrapers, Renmark, S. Australia.

IRRIGATION DISTRIBUTION DITCHES.

These, as a rule, are constructed of earth but where the soil is porous and seepage likely to occur, it is necessary to line them with cement or concrete.

For orchards, concrete distributing ditches are generally formed, with a bottom width of from 6 to 18 inches by about the same depth, and with side slopes

Fig. 10.—The Author's teams at work constructing a main channel with Buckscrapers, Renmark, S. Australia.

of ½ to 1 (Fig. 14 shows exact size of concrete ditch used in my own orchard), but in some cases no slope is given, the sides being vertical. To divert the water

from ditch to furrow short regulating tubes (Fig. 15) are embedded in the concrete at suitable distances.

Fig. 11.—The Author's teams at work constructing a main channel with Buckscrapers, Renmark, S. Australia.

Before you attempt to apply concrete carefully form your earthen ditch and thoroughly soak it with water.

Distributing ditches in orchards have their disadvantages. They occupy valuable space, require continual cleaning (if not concreted), and interfere with cultivation.

To overcome these objections the use of cement or clay pipes placed underground have been introduced. Standpipes are placed at the head of each row of trees to deliver and divide the water among the furrows.

Fig. 12.—Flooding the Tennis Court at a Country Home, S.W. District.

In earthen ditches, and where it is impossible to maintain an even fall, wood, brick, or cement drops are necessary. Fig. 16 shows a brick drop with wooden bulk-head.

To raise the water level in an earthen ditch, and to control a stream, metal tappoons (Fig. 17), or ordinary sacks, can be used.

Fig. 18.—Earthen head ditch in orchard with wooden regulating outlets instead of sluice boxes.

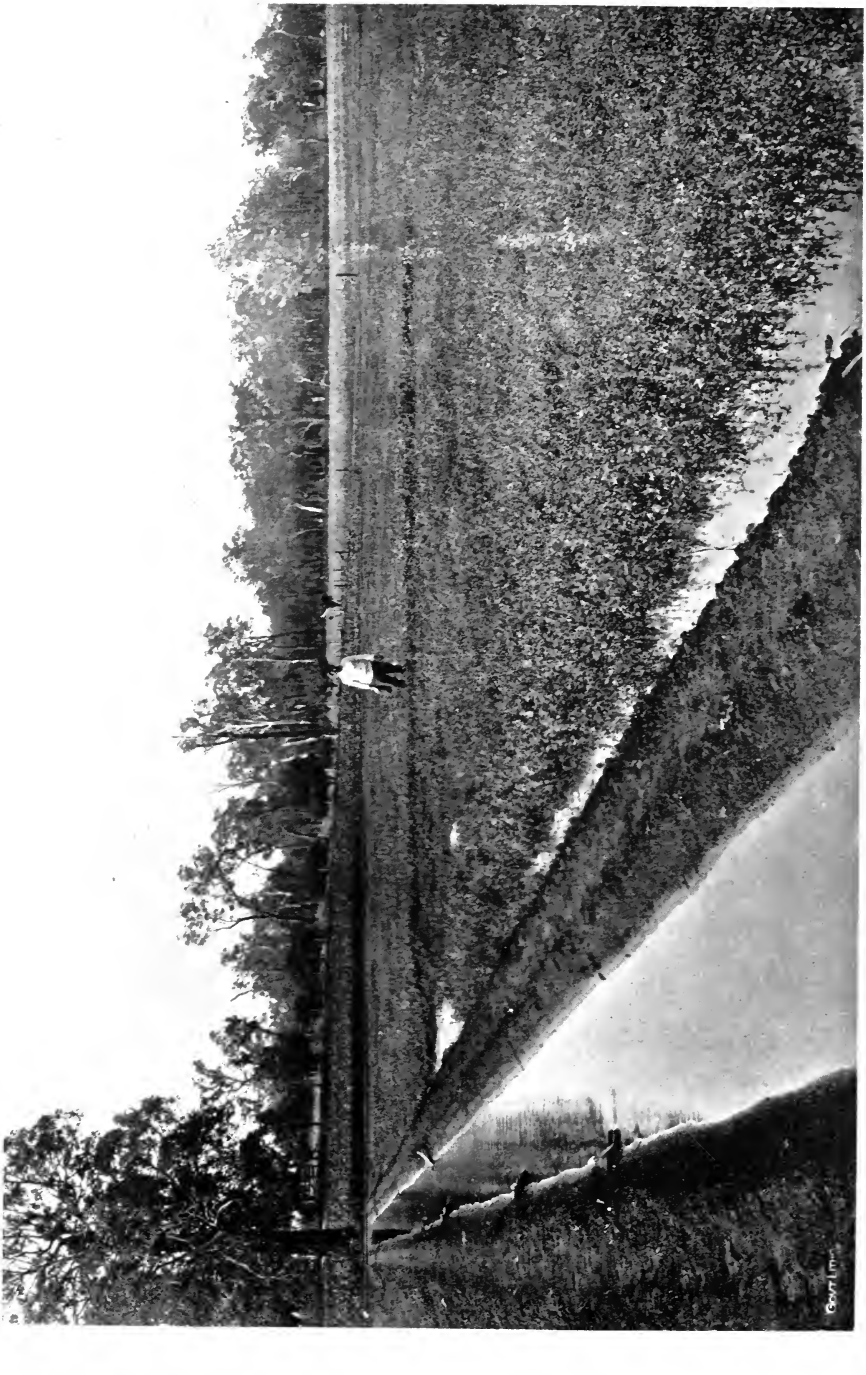


Fig. 13.—Ditch and Regulating Boxes.

FURROW IRRIGATION.

Furrow irrigation is found to be the best for the majority of orchards (Fig. 19), and for all root crops and vegetables. Experience of irrigators shows the following to be its principal advantages and disadvantages:—

Advantages—

(1.) The loss of water due to evaporation and seepage is small.
(2.) Alkali is less liable to rise than with other methods.
(3.) A small head of water can be conveniently and advantageously used.
(4.) There is little displacement of the top soil.
(5.) The soil is moistened chiefly beneath the surface by capillarity.
(6.) The surface soil, after being watered, is not baked, nor hard to cultivate.

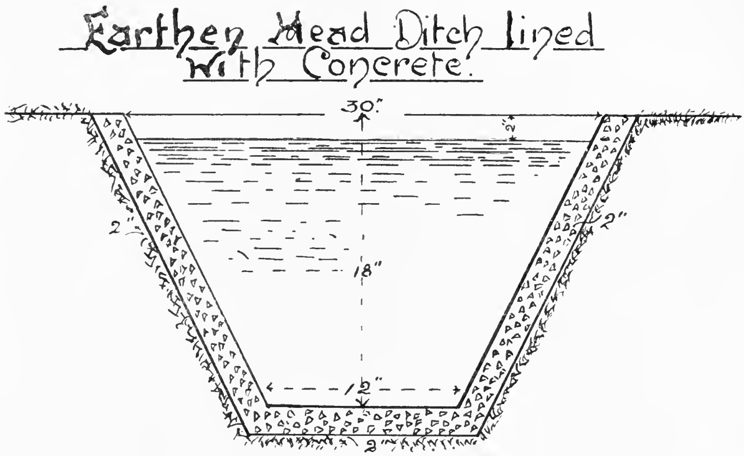


Fig. 14.

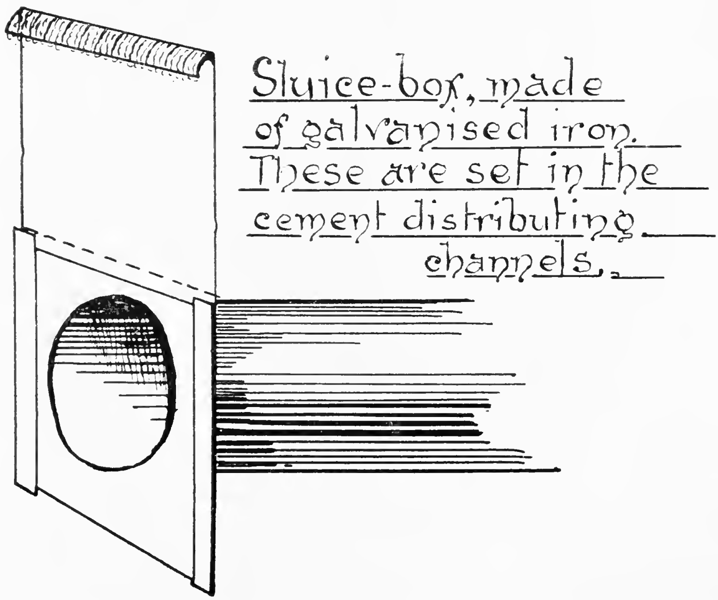


Fig. 15.

Disadvantages—

(1.) Large volumes of water cannot be rapidly applied to a field.

(2.) As commonly practised, the flow in the furrows is unequal.

(3.) It is difficult to distribute the water uniformly on porous soils.

(4.) The upper and lower ends of a furrow seldom receive equal amounts of water.

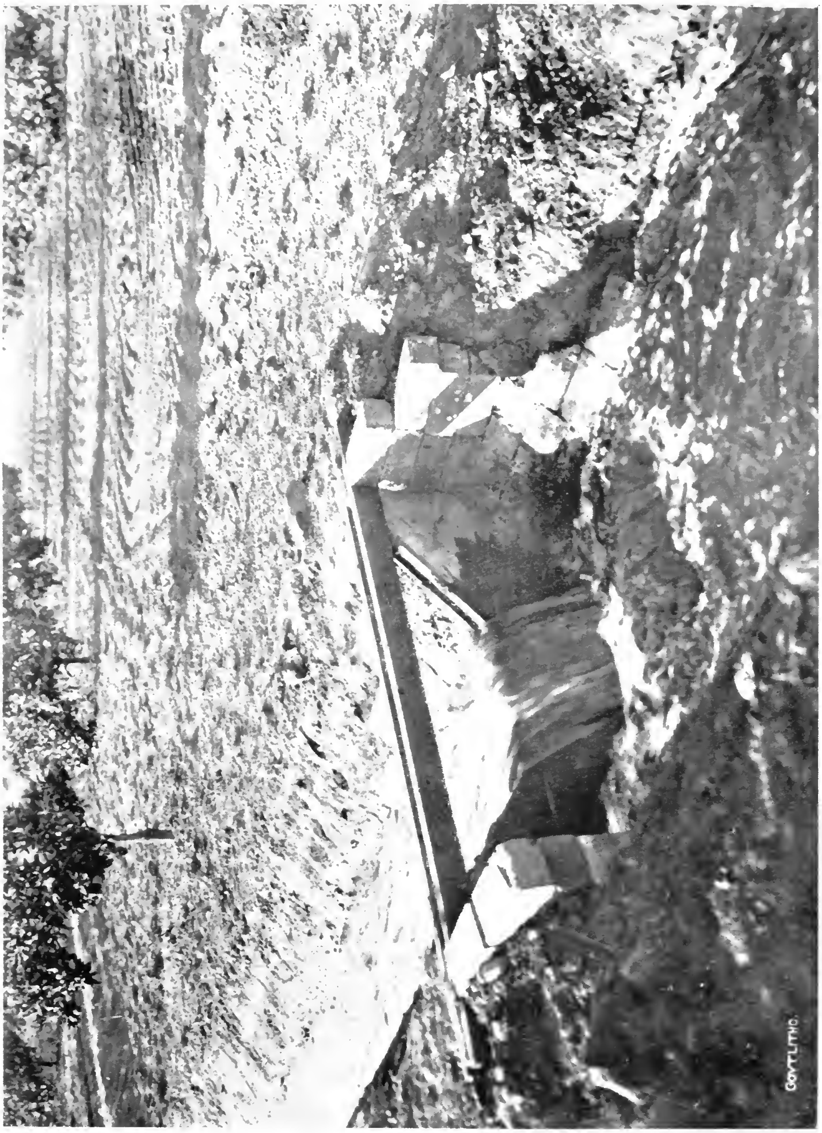


Fig. 16.—Fall or drop constructed with loose bricks in channel.

FLOODING FROM SMALL FIELD DITCHES.

In a general way it may be stated that it is suited to the irrigation of all kinds of grains and grasses. Its advantages and disadvantages are summarized below:—

Advantages—

(1.) In first cost it is one of the cheapest methods.

(2.) It is well adapted to the most common crops.

(3.) Apart from grading, the top soil is not disturbed.
(4.) The small field ditches do not seriously interfere with farming operations.
(5.) It readily adapts itself to the delivery of water in continuous streams.
(6.) Enormous yields have been obtained by the use of this method.

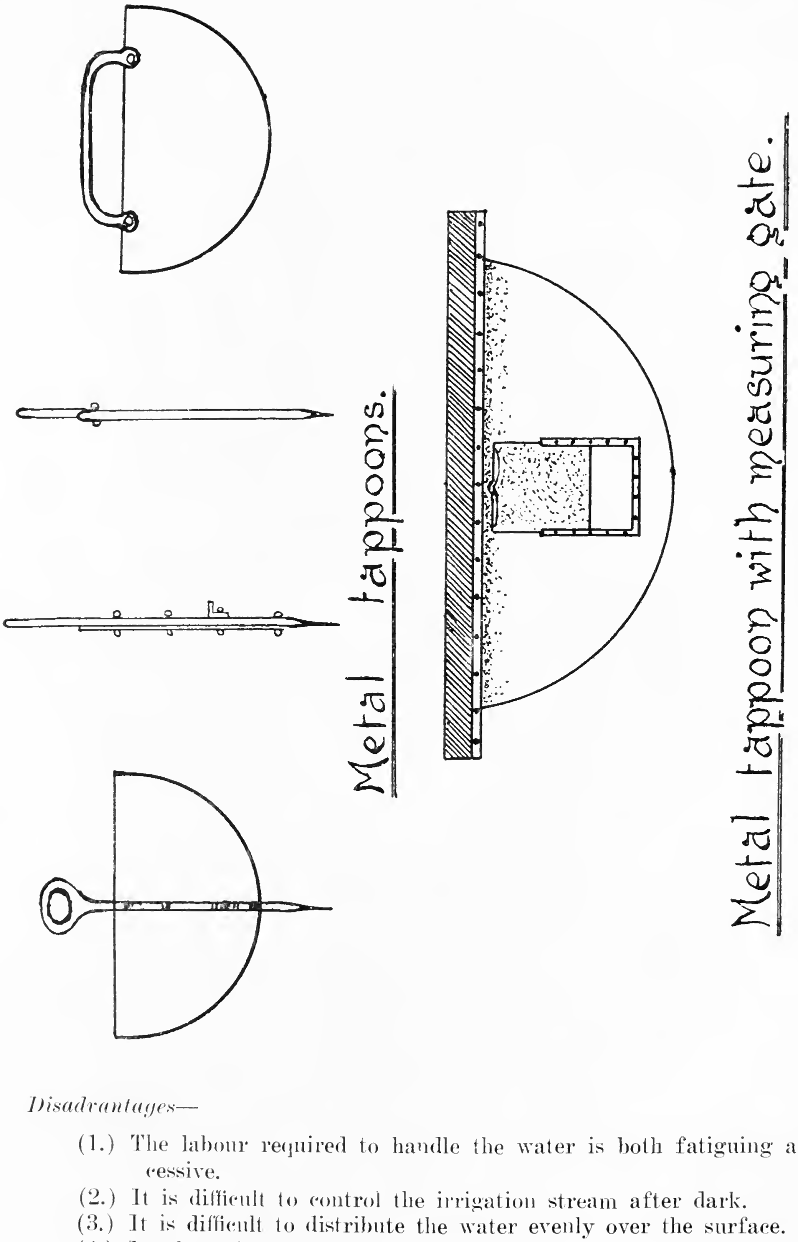


Fig. 17.—Metal Tappoons.

Disadvantages—

(1.) The labour required to handle the water is both fatiguing and excessive.
(2.) It is difficult to control the irrigation stream after dark.
(3.) It is difficult to distribute the water evenly over the surface.
(4.) In all grain crops the field ditches have to be renewed each year.
(5.) The yield is not uniform when the water is unevenly distributed.

THE BASIN METHOD.

The use of "Basins" is confined, for the most part, to orchard irrigation, where

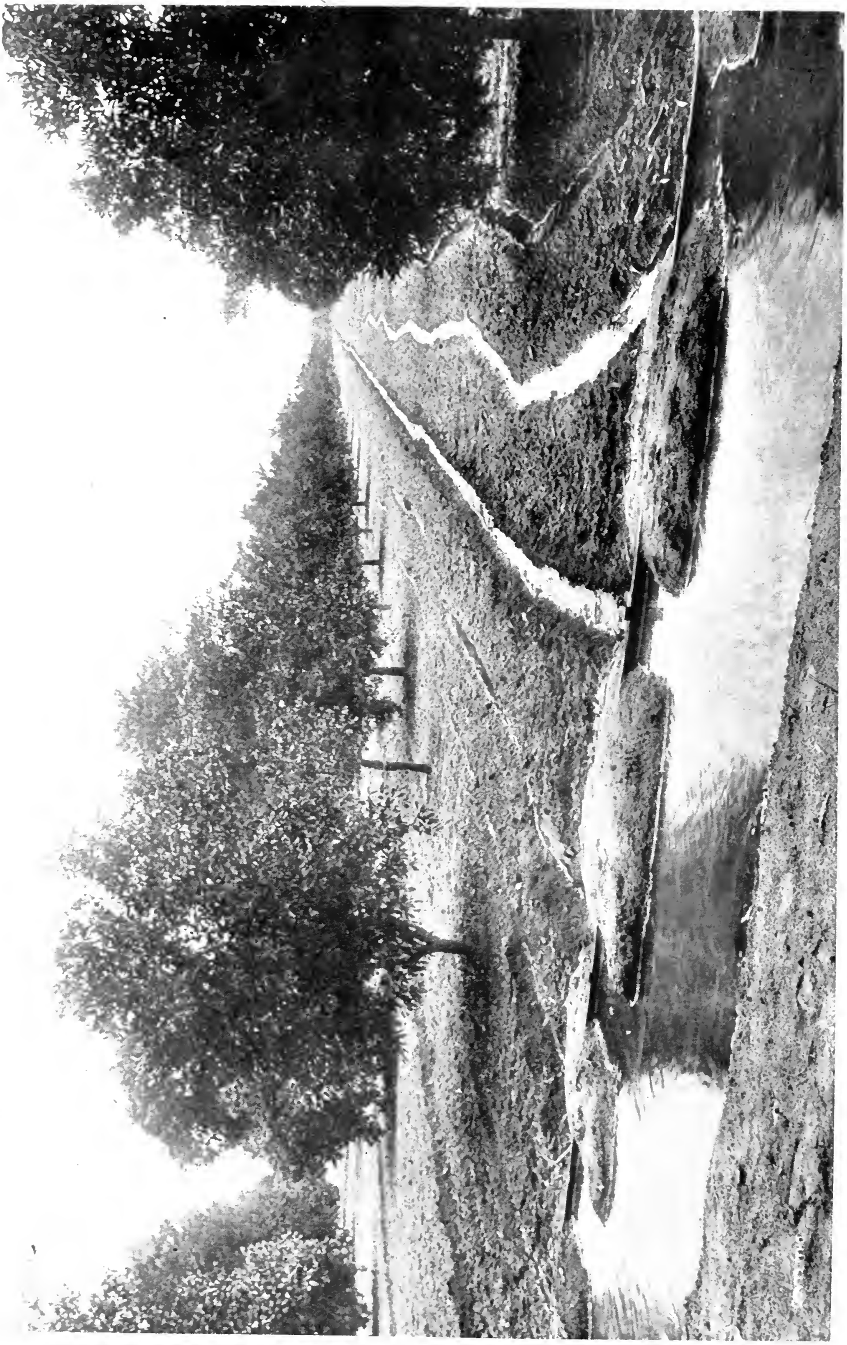


Fig. 18.—Head Ditch in Orchard.

a "Basin" is usually made for each tree, but its use seems to be decreasing rather than increasing. The best conditions for this method are a plentiful supply of

water during the time of irrigating and soils that cannot properly be watered by furrows. It has the following advantages and disadvantages:—

Advantages—

(1.) It permits the use of a large head of water on small areas.
(2.) The time required for applying water is much reduced.

Fig. 19.—Irrigating Orange Trees in the South-West.

(3.) It is well adapted to light-porous soils.
(4.) It is applicable to lands containing soils of widely different texture.

Disadvantages—

(1.) Heavy soils are apt to bake after being flooded.
(2.) It necessitates considerable shifting of soils for each irrigation.
(3.) There is considerable loss from evaporation.

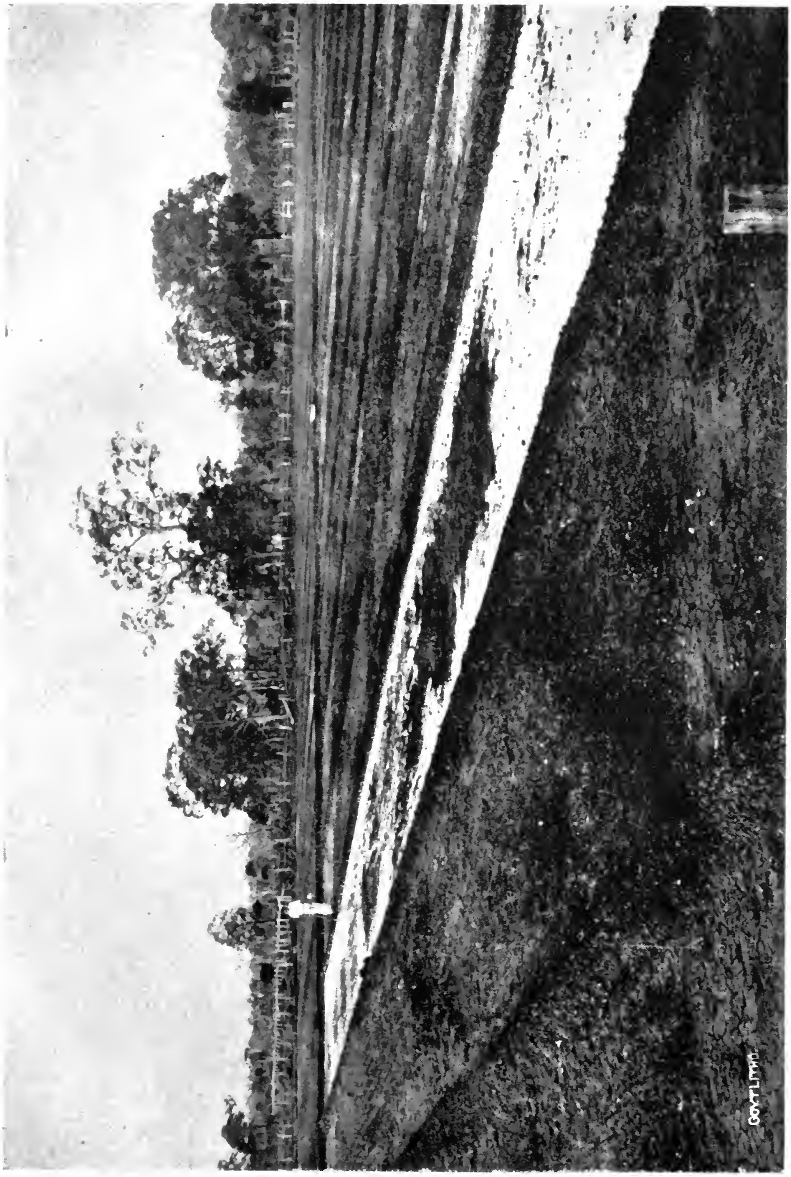


Fig. 20.—Field graded to the Border Method, S.W. District.

(4.) It tends to form a hard-pan beneath the cultivated layer.
(5.) It may bring the roots of trees near the surface.
(6.) The water may scald the trees in summer.

USE OF METAL PIPES AND CANVAS HOSE IN IRRIGATION OF FIELD CROPS.

Advantages—

(1.) Losses which would otherwise occur by seepage in the conveyance of water over a field are prevented. Further loss in application due to crab-holes is also largely eliminated.

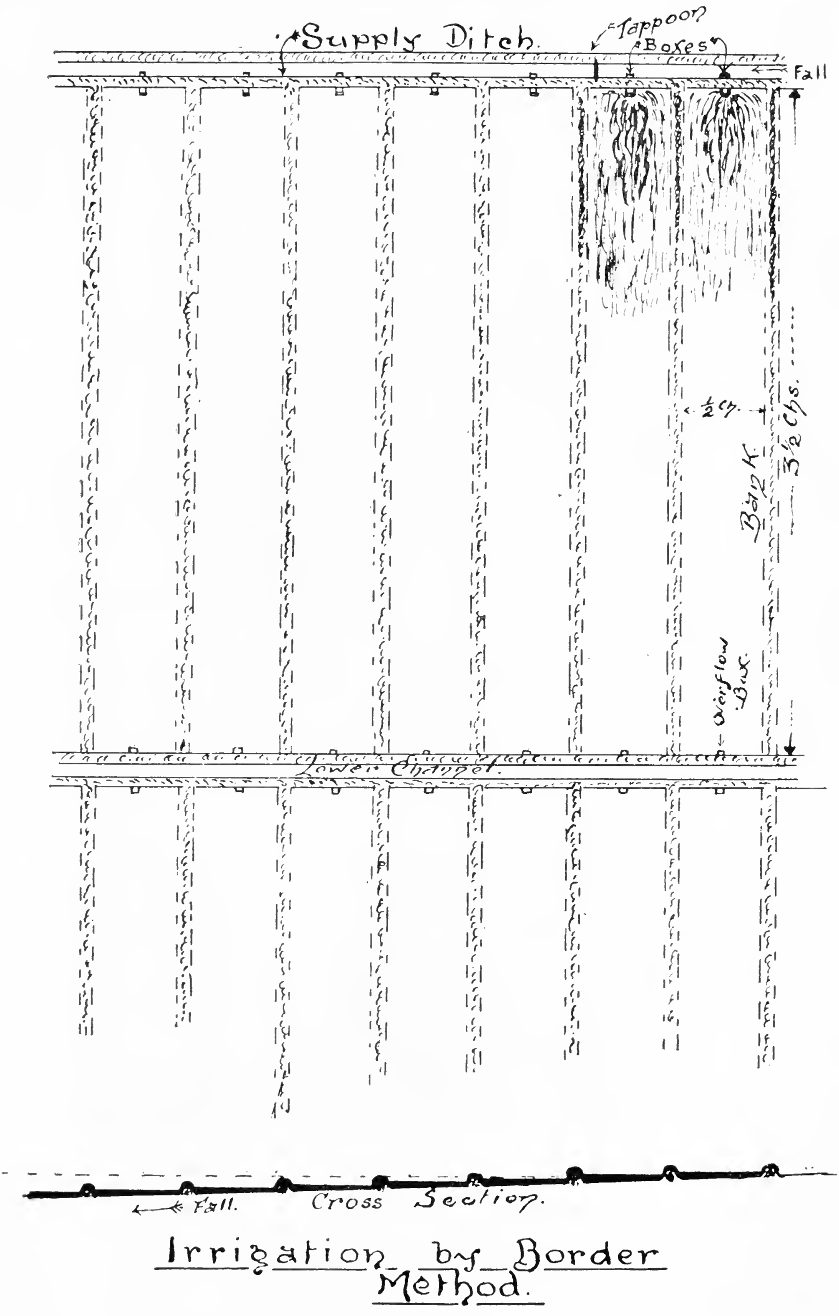


Fig. 21.

(2.) A small stream may be handled effectively over a large area, and the irrigator may apply the stream at any point of the field he desires.

(3.) No field laterals are required, which is a direct saving in the crop-producing area of a field, as well as in the time required to construct and repair these laterals.

Fig. 22.—Serpentine, W.A.

(4.) There are no laterals and the surface of the land is free from obstructions. Crops, therefore, can be harvested with greater ease and with less wear and tear on farming machinery.

(5.) With pipe and hose land can be irrigated with little or no preparation, although it is better to level land to some extent, if it needs it.

Disadvantages—

(1.) Initial cost is high, especially where underground pipes form part of the system.

(2.) Pipe and hose require careful handling to prevent their being damaged. Canvas hose, even with best care, is short lived and requires frequent renewal.

(3.) It is necessary to have pressure head on pipes in order that a fair sized stream may be carried.

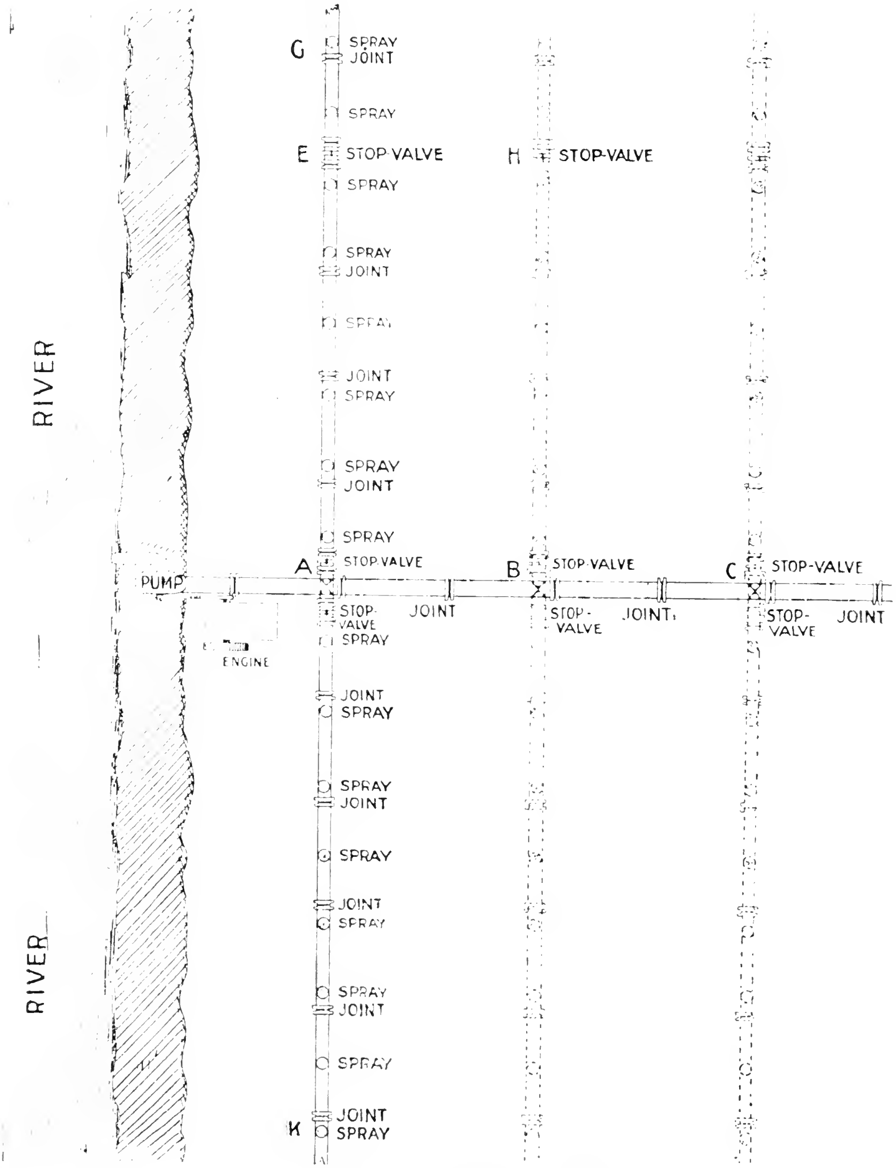


Fig. 23.—Spray or "Over-head" Irrigation—Nunan Movable system. This plan simply shows how the system is applied; method of laying it out will depend on the contour of the ground.

THE BORDER METHOD. (Fig. 20.)

The prominent features of this method are a large head-ditch, and the division of the field into long narrow strips, by borders of earth running in the direction of

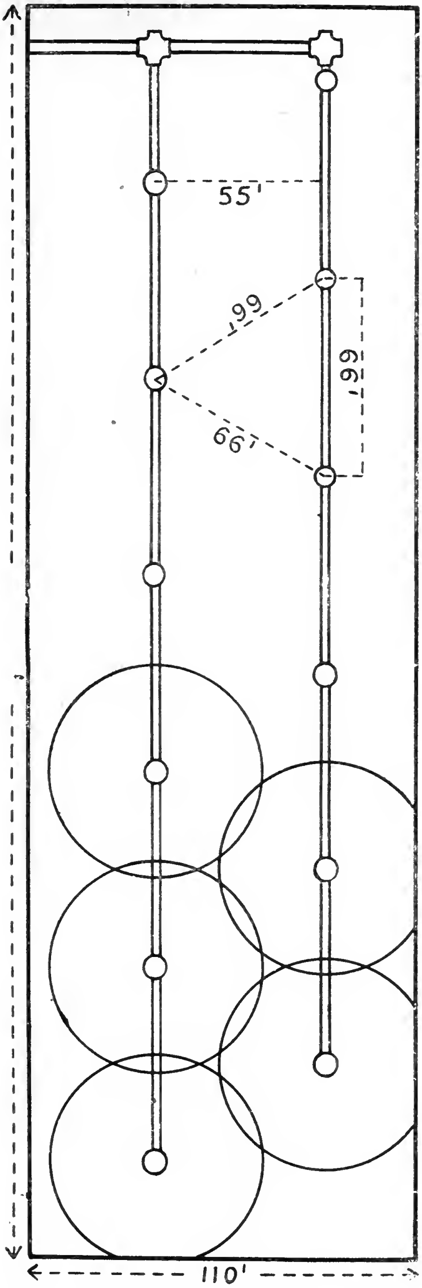


Fig. 24.—Spray System.

the greatest fall. These low ridges, or borders, serve to confine the water within each strip as it slowly traverses the field from top to bottom. It is important to form the space between the borders as nearly level as possible.

The supply ditch is built at right angles to the long side of the borders and enough water should be turned out to cover the whole surface between the ridges. This is kept running until the water has reached three-quarters of the way down the slope, when it should be turned off. The water will reach to the bottom of the plot and if care is experienced no waste should occur.

This is a system of laying out land which can be highly recommended to farmers in this State should conditions permit. Fig. 21 shows a plan of a field laid out by this method.

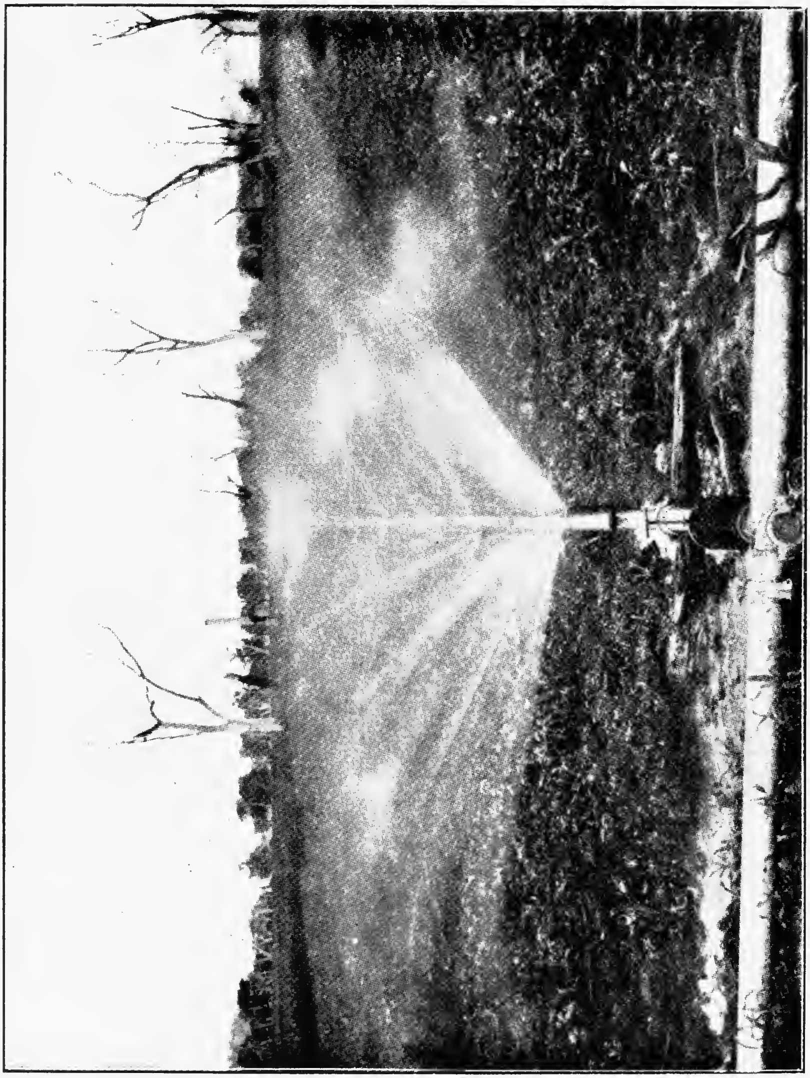


Fig. 25.—Movable Spray System of Irrigation. Nunan's patent.

The plots or strips should not exceed 300 feet long by 40 to 50 feet wide. In several cases, in this State, where economical watering has been practised, the plots were arranged 200 feet long by 33 feet wide. Again, when only a small supply of water is available, it is sometimes necessary to cut the plots even smaller. Fig. 22 shows a contour ditch through an ungraded orchard. Note border system in distance.

IRRIGATION BY SPRINKLERS. (Fig. 23.)

The principal advantage of Spray Irrigation is economy in the use of water, as there are no losses by seepage. The system enables irrigation to be practised when the water supply is limited, and when the ground is uneven and too costly to grade. A small pumping plant forces the water under pressure through the pipes and the land can be subjected to a shower of artificial rain at will. Thus a spray system of irrigation resembles somewhat the water system of towns and cities, and can be used in the homestead and barns for such purposes as supplying all the water for domestic use.

It is not economy to use small pipes, because of the loss by friction. Windmill power and overhead tanks can be used for irrigating small areas, and a head of not less than 20 or 25 feet should be arranged so as to allow for necessary pressure.

Fig. 26.—Movable Pipe System. Joint (Light Pipe).

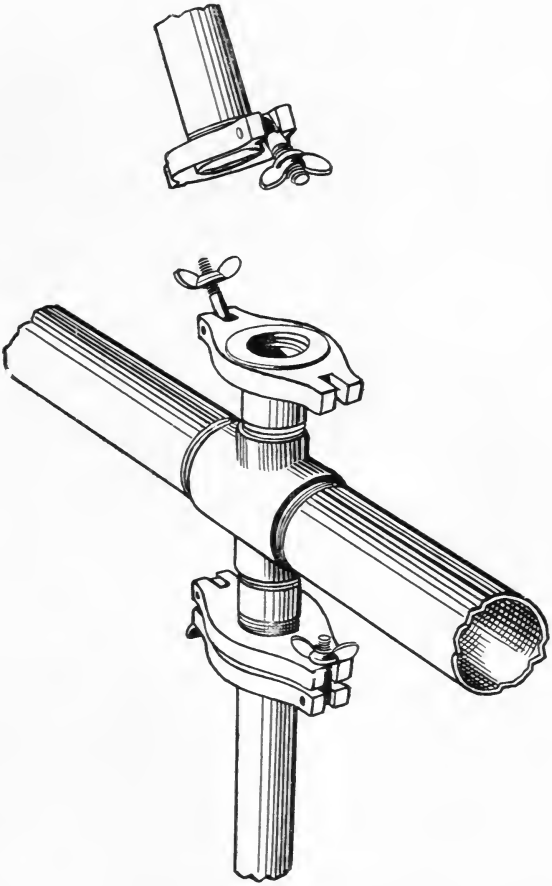


Fig. 27.—Movable Pipe System. Quick Coupling Flanged Joint (Heavy Pipe).

Again, there are many cases in which the method of flooding or furrow irrigation are unsuitable. Where the surface of the ground is hilly, irregular, or where the land is too valuable to be occupied by furrows or water channels, these and other conditions will be favourable to a system of spraying.

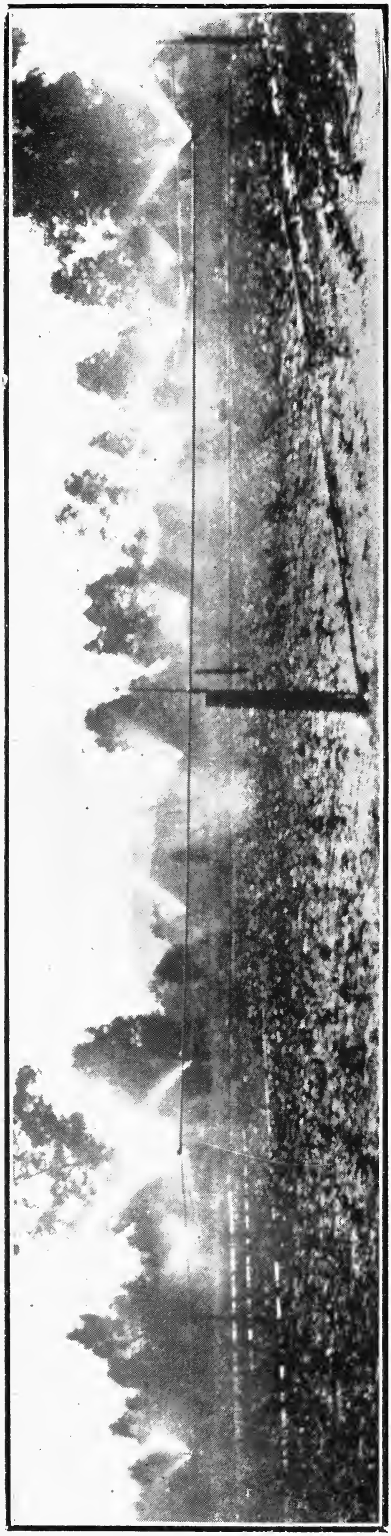


Fig. 28.—Spray or "Over-head" Irrigation, Serpentine, W.A., Stewart & Lloyd's System, with O'Grady Patent Sprinklers.

In some cases the pipes are laid about a foot beneath the surface (Fig. 24) or so far that they can never be disturbed by the plough. The size and distance apart of pipes must be controlled by the head or pressure of the water supply.

The movable pipe system (Figs. 25, 26, and 27) is also extensively used and has the advantage of being less costly in the initial outlay, but it entails more labour in operating. The use of sprinklers has been found very satisfactory in hilly grounds—the water can be regulated and evenly distributed in such a manner that none is wasted or the soil displaced. The soil is not so liable to cake or form a crust, thus diminishing a very serious difficulty which exists in most other methods of watering.

Fig. 28A.—Spray Irrigation—Skinner System.

In vegetable growing it has been found effective in keeping under control insect pests, and the foliage retains a healthy colour (Fig. 28). Evaporation is naturally high, but this can be avoided to a great extent by watering in the early morning and late in the evening. (Fig. 28a.)

The system is costly, but splendid results are obtained, especially by market gardeners and small fruit growers (Fig. 29).

UNDERGROUND OR SUB-IRRIGATION BY PIPES.

Underground irrigation by pipes is practically non-existent. A number of text books have been published on this subject, and the theory outlined looks so wonderfully simple and economical that one marvels why farmers are so slow in adopting it. Ask anyone who has tried it, however, and you will get the reason. It is a delightful theory, but nothing more.

The difficulty has been to devise a system of underground pipes with enough openings and of a size to admit a sufficient quantity of water to the soil without the openings being eventually filled up by roots in their natural growth towards

moisture. Sub-irrigation by means of underground pipes has been tried in Western Australia and theoretically both labour and water were to be saved; the scheme was, however, a complete failure.

While in California I visited several farms where this method of applying had been tried and abandoned, and I am convinced that no system of underground pipe irrigation has yet been discovered to displace the present system of surface watering.

ARTESIAN WATER.

Some artesian water can be used successfully for irrigation. Many classes of water are found, some suitable, but others being alkaline have an injurious effect on vegetation and soil when used for irrigation purposes.

Elaborate tests have been made in the United States of America to determine the effect of artesian water on fodder plants, fruit trees, and vegetation, and how far the injurious effect of alkali can be counteracted.

It is generally considered that when bore water contains more than 45 to 50 grains per gallon of those forms of saline matter which are known to be deleterious to plant life it is unsafe for continual irrigation. A most essential thing, therefore, before preparing for irrigation, is to forward a sample of water to the Department for analysis. The reduced fee to *bona fide* settlers for this work is 5s. per sample.

It must be admitted that in some cases waters are too saline and ruin the soil, but satisfactory results can be obtained from many bores if the water is applied judiciously. Any water, whether from a river, well or bore, if indiscriminately applied, without underground drainage, will sour and waterlog the soil and eventually kill the land.

I have seen many artesian bores put down on inconvenient or low portions of an estate. The water cannot then be used to the best advantage without expensive fluming or a power plant. See then that your bore is placed on higher ground than that to be irrigated. Aeration may be necessary in some cases. Water should not be applied if the temperature is above the 100deg. F. Some classes of fodder naturally can stand a greater temperature than others. I firmly believe that in years to come portions of our North-West, under a systematic method of water conservation, will become as rich and fertile as any part of Australia.

Irrigation has been practised for some years with success from bores near Perth. The Claremont Asylum farm is an excellent example of artesian irrigation, and splendid crops of lucerne and other fodders have been produced.

It may be of interest to many to know that the artesian bores of Western Australia are yielding approximately 30,000,000 gallons of water per day.

RESERVOIRS AND DAMS.

The use of reservoirs and dams in this State for storing water for irrigation purposes has so far received little attention.

Reservoirs may be divided into two classes, natural and artificial. In the first class are included reservoirs where the greater part of the retaining banks are formed by nature, while, on the other hand, artificial reservoirs are those in which practically all the banks are artificially constructed.

Natural reservoirs are used for the storage of river or rain water, not only for its various economic uses, but also, in some cases, to equalise the flow of rivers and to minimise the danger of floods.

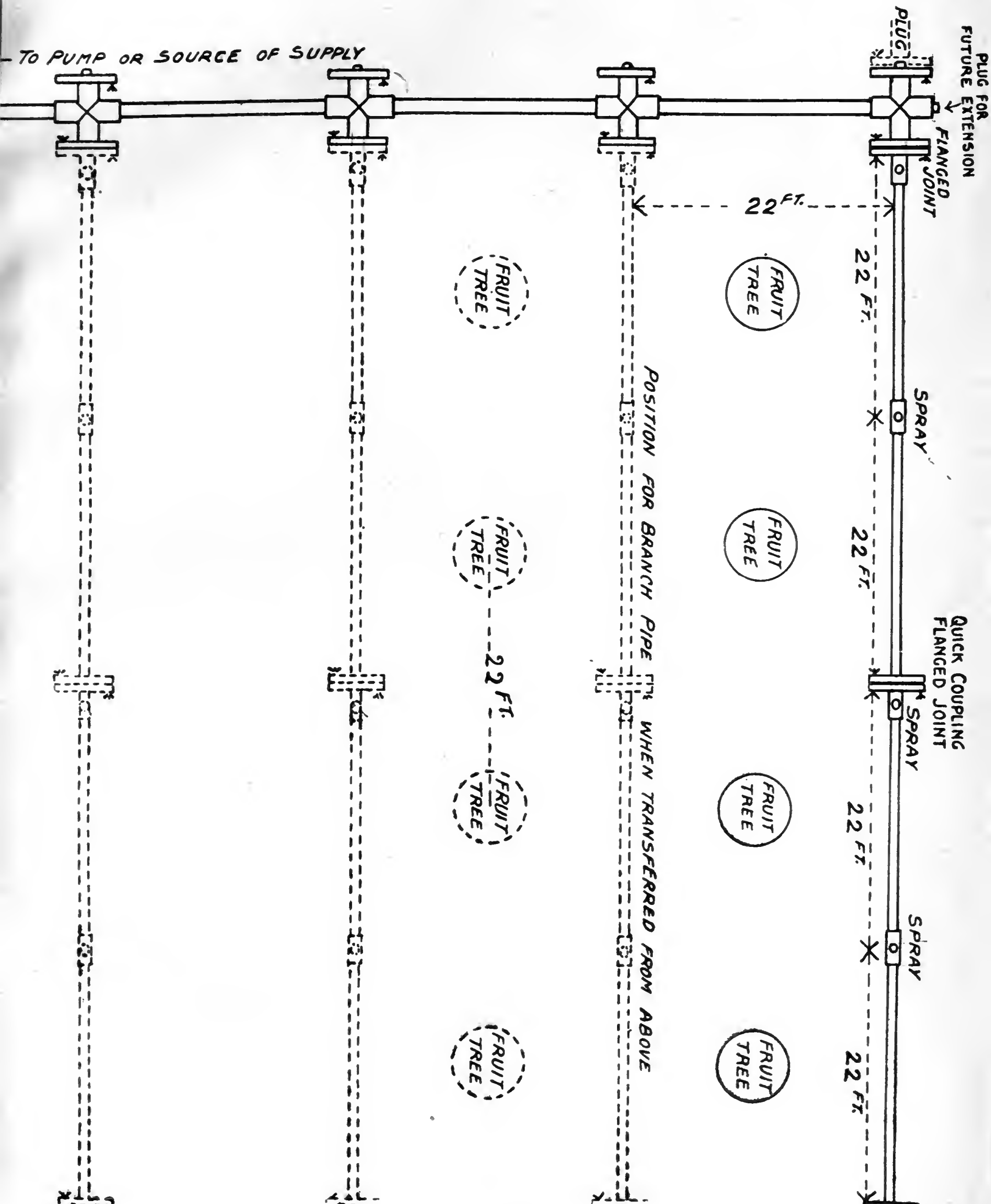


Fig. 29.—Movable Pipe System for Orchards (Messrs. Stewart & Lloyd).

Small artificial reservoirs serve the following purposes:—

(1.) They will permit a continuous 24-hour operation of pumping plants, or flow from artesian wells, without night irrigation, storing water during the night and irrigating with it during the day.

(2.) They allow the use of irrigation heads larger than the rate of the supply to the reservoir, thus reducing the percentage of seepage and losses in the distributing ditches.

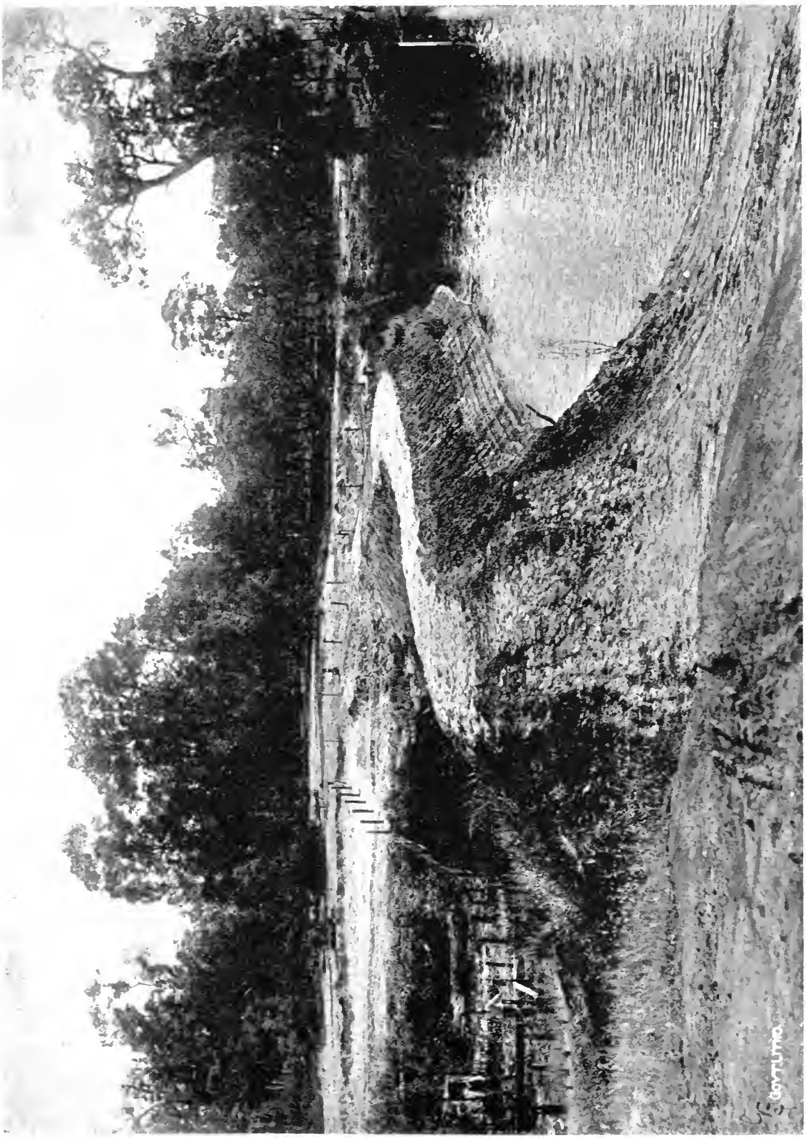


Fig. 30.—Earth Dam or Reservoir supplied by Springs, Upper Swan, W.A.

(3.) The quantity of water which one man is capable of handling may be more easily supplied in this manner thus reducing the cost of labour for irrigation.

Fig. 30 shows a dam supplied mostly by springs, situated on the property of Mr. Barrett-Lennard, Upper Swan, the water conserved being used for the irrigation of his large vineyard.

Fig. 31.—Sack Dam and Measuring Weir on Stream, W.A.

Where expense is a consideration small sack dams can be used with advantage during the summer months in many of our small streams and gulleys (Fig. 31).

Osborne Park is an example of what intense culture, drainage, and irrigation can perform. Fig. 32 illustrates an irrigation lock constructed with timber on the main drain

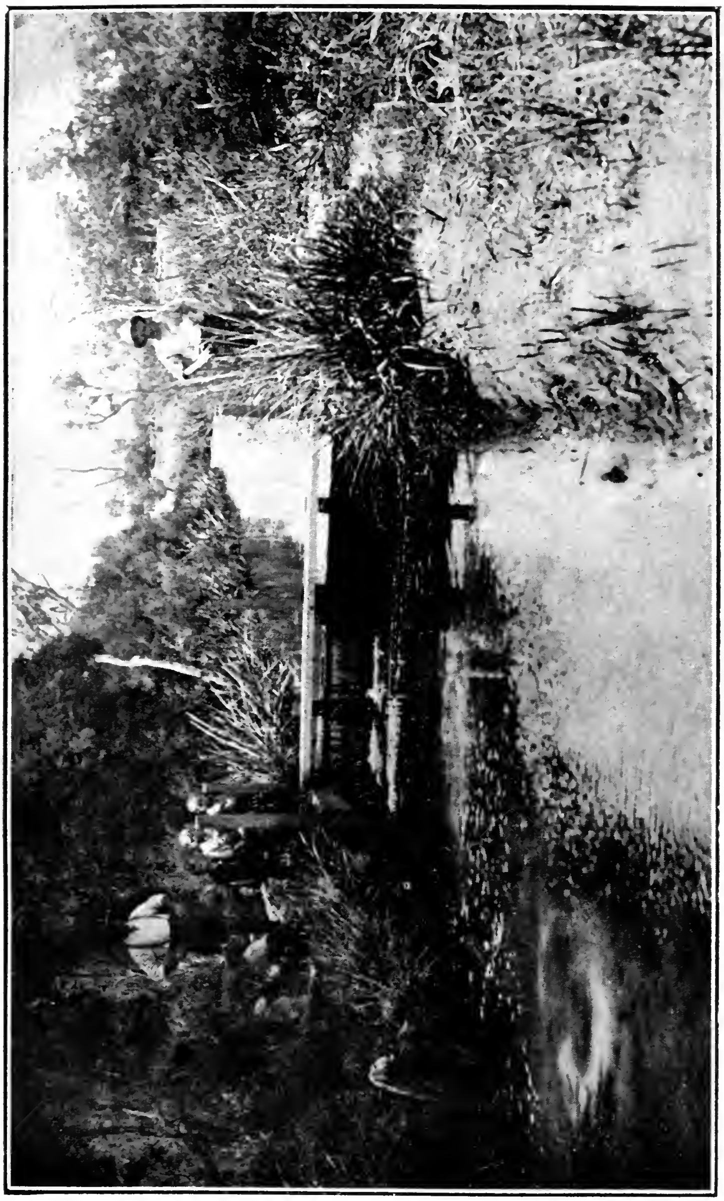


Fig. 32.—Osborne Park—Irrigation Lock, Main Drain.

APPLICATION OF WATER.

In the application of water to land practical and local knowledge is essential if the best results are to be obtained. The furrow system will be found best suited for watering trees and the majority of crops (Fig. 33).

The length of the furrows and distance apart must be regulated by the soil and general conditions, but a length generally of from 6 to 10 chains will be found

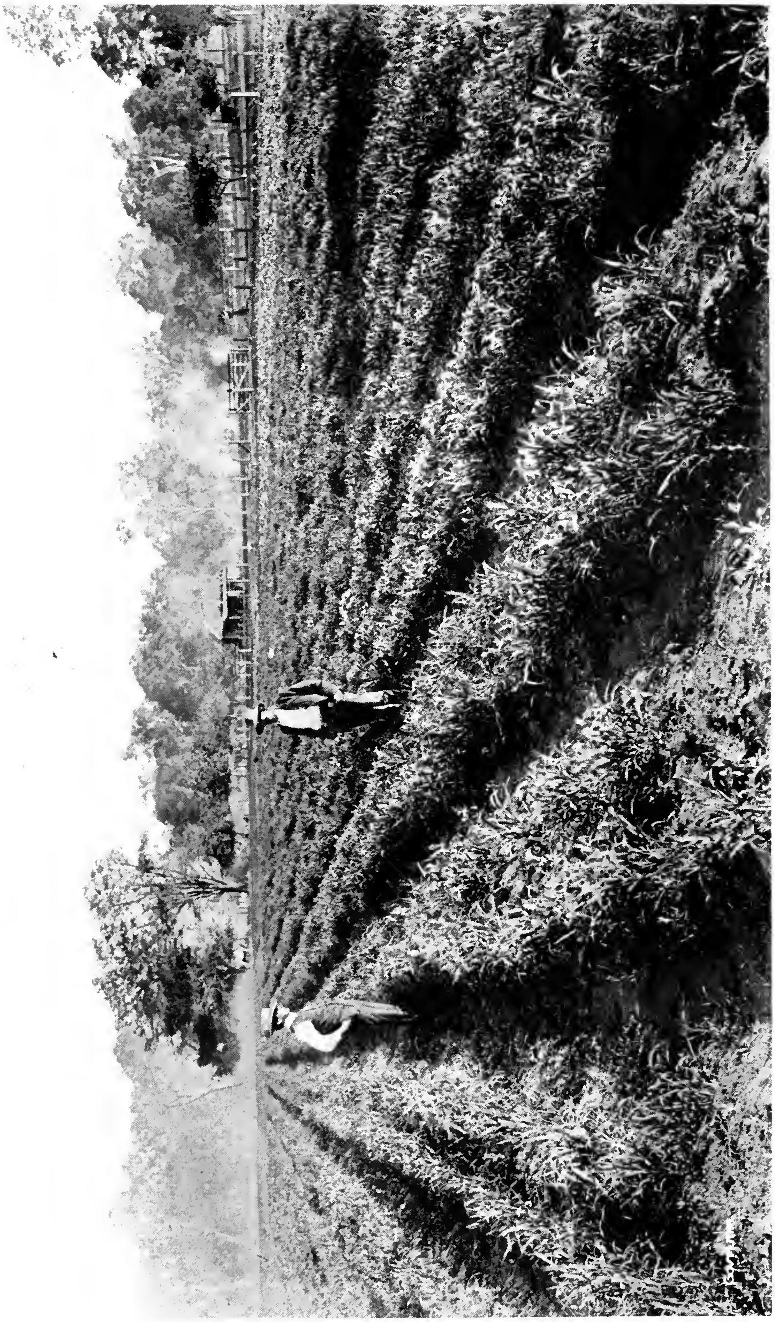


Fig. 33.—Young Millet, showing system of irrigating furrows, Wellington District.

most economical. A large head furrow running parallel with the supply ditch should always be run, as this will simplify the process of dividing the water evenly

down each furrow. If the distribution of the water in the furrows becomes unequal, this can be corrected by placing weeds, rubbish, or old sacking in the furrows and so checking the flow. Sluice boxes constructed of wood (Fig. 34), galvanised iron, or pipes set in the ditch allow the stream to be fully controlled by quite young lads, who take readily to the work (Fig. 35).

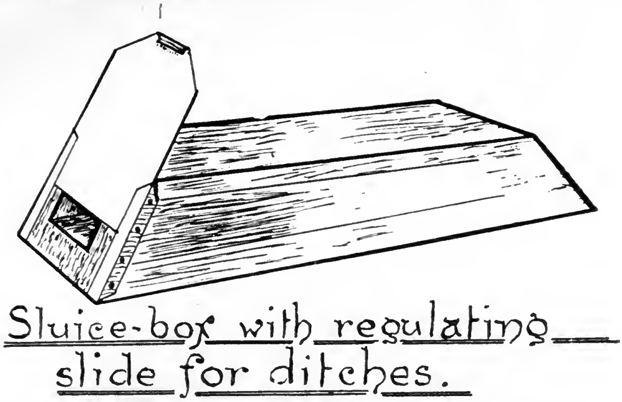


Fig. 34.—Sluice Box with Regulating Slide for Ditches.

THE TIME TO IRRIGATE.

The time to irrigate is learned by experience in each locality, for local conditions vary greatly. In general, however, a change in the colour of crops indicates their need of water. As the supply of moisture in the soil begins to be exhausted the plants turn a darker green than the normal colour, the lower leaves turn yellowish, and some of the leaves may drop and curl. When these signs are observed water should be applied at once so as to prevent permanent stunting of the crop.

In areas of field crops which are planted in rows and in orchards and vegetable plots cultivation of the soil should follow as soon as possible after irrigation, in order to conserve the supply of moisture and prevent caking of the superficial layer of the soil. Some soils bake on the surface after irrigation. In such soils irrigation should precede the planting of the crop. When water is applied after sowing time, for the purpose of making the seed germinate, the ground is baked so hard at the surface that the grain is unable to stool.

There is a saving of both water and labour in having command of a good flow of water when irrigating. This is the case in all methods of distribution, and especially so in flooding (Fig. 36).

The economy in working with a liberal command of water is shown by the fact that a stream of water delivering, say, 500 gallons per minute will irrigate much more land in one hour than one delivering 250 gallons per minute will irrigate in two hours.

It may be asked "How much water will I require to apply to my orchard?" Taking general conditions in our fruit-growing districts into consideration provision should be made for one acre-foot, or say, roughly, 250,000 gallons. In many cases it will not be necessary to apply this amount but, in laying out a scheme of watering, try and arrange to have this amount available if possible.

I have advised on most of the orchard irrigation projects in this State, and, when the furrow system has been employed, two waterings of four or five inches each have been found ample.

Lucerne requires a very large quantity of water, and two to three acre-feet should be provided, if available, if the plant is to be grown successfully.

For maize, sorghum, and millet the same amount of water that is required for orchards will suffice.

OVER-IRRIGATED LANDS.

Irrigation to many localities is a veritable boon and yet may have its harmful as well as its beneficial, influences. I have seen many cases where water has been allowed to run so long on land that the soil has been rendered useless.

Fig. 35.—Young Irrigators, W.A.

Over irrigated crops develop a sickly yellowish-green colour. Where water is plentiful the mistake of using too much is, perhaps, more frequent than that of not using enough. Inexperienced irrigators sometimes seem to think that irrigation consists simply in having plenty of water and turning it upon the crops, but the

necessity of giving close attention to local conditions in successful irrigation is being gradually realised.

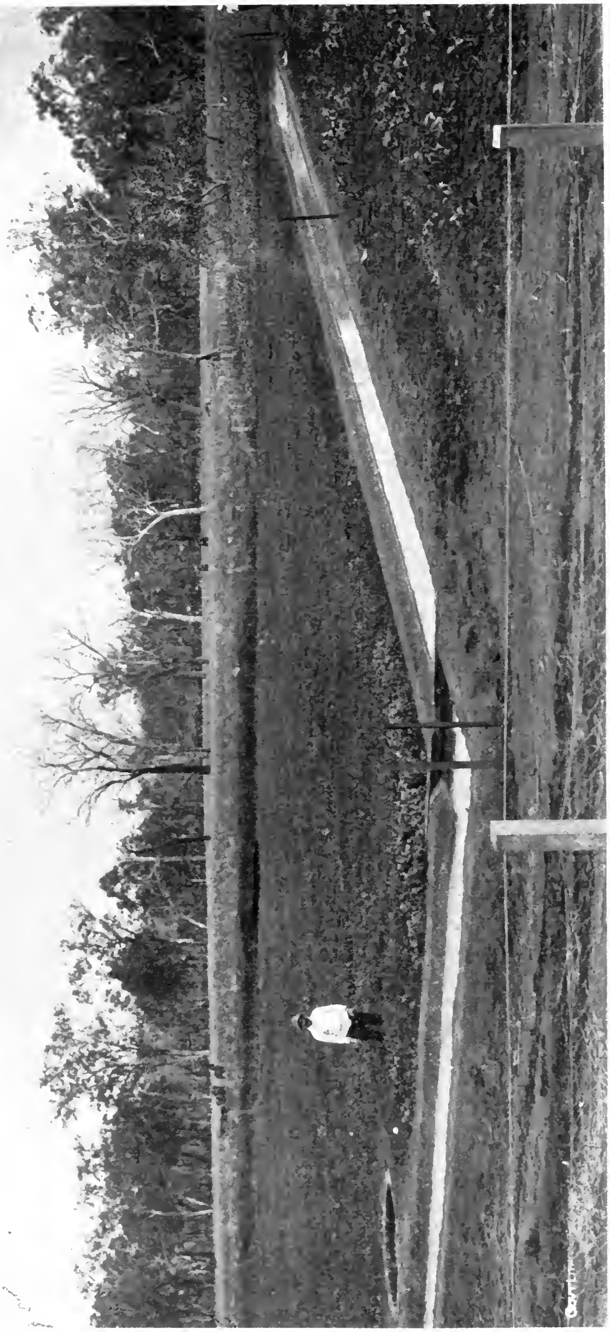


Fig. 36.—Irrigation, W.A.

Over-irrigation is generally found where water is easily obtainable and is led on to the farm by means of gravitation.

LUCERNE UNDER IRRIGATION.

The word Alfalfa, or lucerne as it is called in Australia, is derived from an Arabic word meaning "the best fodder," which honour it can certainly still claim. Lucerne, under irrigation, is going to assist many a farm in this State, and a few points on how to irrigate this valuable fodder may be of value.

While the amount of water applied and the time of its application must be largely governed by the nature of the soil and the weather conditions, the system of flooding is the universal method used. Under this method of irrigation a uniform distribution of water over the surface of the land is the prime object to be attained. Hence the preparation of the land is the first and most important factor in the proper irrigation of lucerne. The better the land is levelled, checked, and supplied with distributing channels, the better the result in spreading the water a uniform depth over the land. He who plants lucerne should remember that the work being done is not temporary, but must stand for years, and that the time and labour expended in the proper preparation of land is an investment. The saving of water alone in the amount required for irrigation on land properly

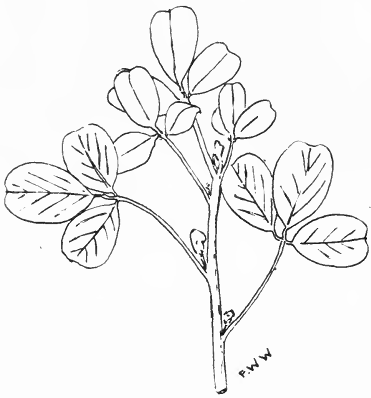


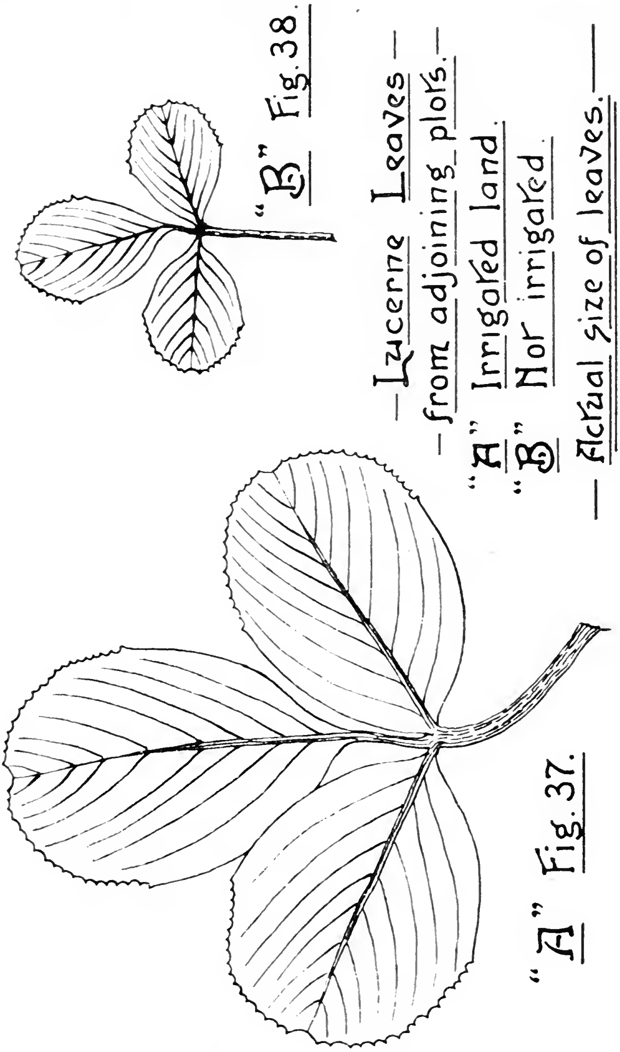
Fig. 37

graded, etc., will soon repay the expense incurred in thoroughly doing the work, to say nothing of the increased yield of the lucerne as a result of proper irrigation.

The system of laying out the land will depend upon the topography of the land to be irrigated, and the amount of land to be enclosed in each tier of checks should be governed by the volume of water available for irrigation purposes.

The greater volume of water the farther apart the checks may be placed, and contrawise for a small water supply. The checks themesleves, or ridges, should in all cases be built with scrapers and should have sufficient width of base to enable them to be broad and rounding at the top so the mower and rake can pass over them with ease, and that the lucerne may find sufficient surface on the top of the ridges to form a sod uniform in thickness with the level land. When the water supply is cheap and abundant, the water may be spread over the land by drawing it from check to check, but where the supply of water is limited, a great saving will be accomplished if the land is plentifully supplied with small ditches from which the water can be delivered into the plots, thus preventing the continuous flow of water from one tier of checks to aonther, which is wasteful owing to the fact that the first tier of checks into which the water is delivered will receive a greater amount of water than is actually required, while the last checks will possibly not receive a sufficient quantity.

In pump irrigation (by this we mean where the water for irrigation is supplied with pumps) small checks and numerous supply ditches are an absolute necessity for economical watering, and, under this system, it is better to carry the water to the point farthest from the pump to commence irrigation. Then, if for any reason the pump has to be shut down and the water supply stopped, it is not necessary to traverse the same land a second time in the delivery of the water. When lucerne is established and where the water is close to the surface of the earth, frequent irrigations are not so necessary.



On sandy or gravelly land, where the surface water is not close enough to the surface to furnish natural sub-irrigation, the amount of water applied must be greater and the number of irrigations more frequent. Where the water supply is available at all times an irrigation of from three to six inches after each cutting will be the best method of irrigation upon lands that have no sub-irrigating supply.

To do effectual irrigation the farmer needs a good sized head of water. A very small stream soaks away too fast and cannot be spread over sufficient land. On land which lies well for irrigation an experienced irrigator can handle a flow of from two to three cubic feet (750 to 1,125 gallons) per minute.

Wilcox, in his "Irrigation Farming," states:—"The critical time with lucerne is the first six weeks of its growth. Flooding during this period is quite certain to give the plant a set-back from which it seldom fully recovers before the second, and sometimes not before the third year, and it is not often in the dry States that rain falls with sufficient frequency to dispense with the necessity for irrigating the plants while small. By soaking the earth from 36 to 48 hours before seeding, however, the plants will make vigorous growth until they are ten to twelve inches high, after which they may be irrigated with safety.

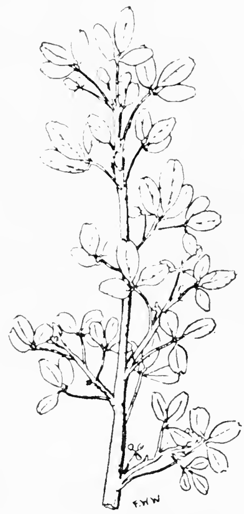


Fig. 38.

"When lucerne has become established, a single copious irrigation after each cutting, will, under ordinary conditions, be found sufficient. Irrigation before cutting is undesirable because it leaves the earth so soft as to interfere with the movement of machinery and load. It also makes the stalks more 'soppy,' and, while they will retain the leaves better, there is more difficulty to be experienced in the curing at harvest time; taking all things into consideration it is much better to irrigate after each cutting.

"In some respects lucerne does not seem to be a natural pasture plant. The stems are delicate; it will not thrive in hard trampled soil, and the crowns, when broken off, will not revive. These peculiarities would at least indicate that it should not be pastured at all until it has become established. Not an animal should be turned on a lucerne field until the second or third year, if it is desired that the 'stand' or plot should endure for several years; nor should it be pastured too early in the spring or too late in the fall."

Coburn, in his book on "Lucerne," states:—"Lucerne does not exhaust the soil. Nitrogen is the soil's most important element, and the one most liable to give out; the one the farmer is called upon to supply first. Lucerne does not ask the farmer for nitrogen at all, because it can get its nitrogen out of the atmosphere.

"I know one farmer who, for the past eight years, has made an average of 8½ tons of lucerne on irrigated land in the State of Washington. I have heard

of other men that produced 12 tons an acre in Southern Texas on irrigated land. It would hardly be possible to produce that much on land that is not irrigated, because rain does not come to order.

"I have lived ten years in a country where the horses, sheep, hogs, and chickens eat lucerne hay, or green lucerne, the year round. It is the richest hay food known. Eleven pounds of it is worth as much for feeding purposes as ten pounds of bran. Lucerne is very long lived. Its usual life in the United States is probably from ten to twenty years, although there is a field in New York that has been successively mown for over sixty years."

In arid districts, and during very hot weather I have found it beneficial to water a few days before cutting, as the water is protected by the foliage and soaks better into the ground. The danger of injury to the plant by sun-scald is thus removed.

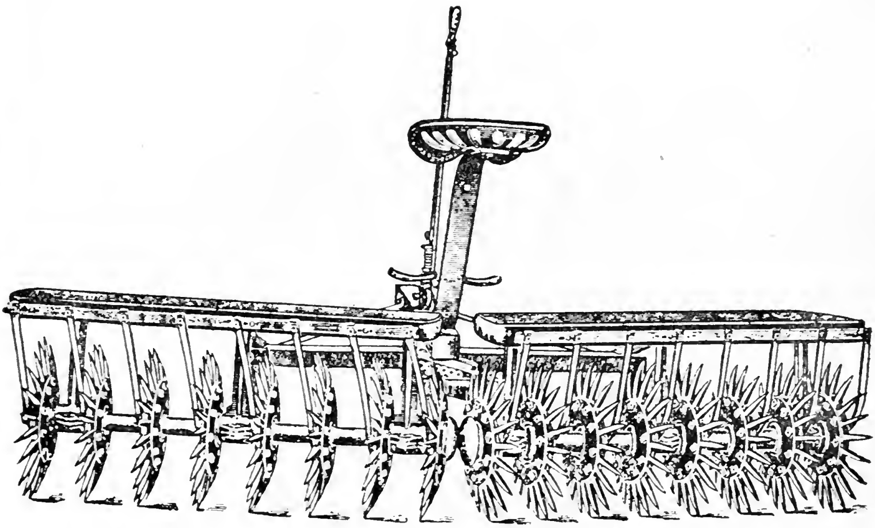


Fig. 39.—Rotary Spike Cultivator for Lucerne.

The chief value of lucerne is in the leaf, and Figs. 37 and 38 show the vast difference between irrigated and unirrigated lucerne. The illustrations are taken from plants sown at the Brunswick State Farm on the same day. Seed from the same parcel was planted in the same soil within a few yards of each other, the conditions being similar except that one was irrigated and the other not. These illustrations are drawn to the same scale.

On the karri country of the South-West lucerne will, with correct treatment, grow luxuriantly without irrigation, but elsewhere, unless sown on particularly favourable spots, it is preferable to grow it under irrigation during the summer months. Other leguminous plants have somewhat similar nutritive properties to those of lucerne, but they are mostly annuals or biennials. Amongst these are the crimson and other clovers, field peas, and vetches. They do not require the same amount of expenditure on the preparation of the ground and providing for its watering as is the case with lucerne, and, for that reason, can be grown over wider areas.

The cultivation of lucerne will be found very beneficial both on irrigated and unirrigated land. Fig. 39 shows a Rotary Spike Cultivator—an implement which can be thoroughly recommended.

Where large areas of lucerne have to be harvested it pays to use up-to-date labour-saving machinery. Figs. 40, 41, and 42 show a lucerne harvester and stacker at work.

If lucerne is sown in the autumn, April and May are the best months. In our heavy rainfall districts it is advisable to sow in the spring, either in August or September.

Fig. 40.—Harvesting and Stacking Lucerne.

TIME TO CUT.

Note the shooting out near the surface of the ground of small new sprouts or buds, as though the plant was about to make new growth. As soon as these shoots appear cut the crop as promptly as possible. The hay will be all the more nutritious, and the stronger will be the new growth. Thus the total amount of hay pro-

duced by a field of lucerne is very directly proportionate to the promptness with which the lucerne is cut after it is ready.

Fig. 41.—Harvesting and Stacking Lucerne.

The number of irrigations and cuttings of lucerne on the Brunswick State Farm for the years 1909-1910 are shown hereunder:—

Cuttings—1909.

No. of Plot	1st.	2nd.	3rd.	4th.	5th.	6th.	7th.	8th.	9th.
1	14 Jan.	13 Feb.	19 Mar.	26 Apl.	16 June	17 Sept.	2 Nov.	11 Dec.	
2	8 Jan.	11 Feb.	17 Mar.	26 Apl.	16 June	17 Sept.	2 Nov.	9 Dec.	
3	7 Jan.	10 Feb.	15 Mar.	24 Apl.	16 June	17 Sept.	2 Nov.	8 Dec.	
4	4 Jan.	8 Feo.	12 Mar.	19 Apl.	15 June	14 Sept.	29 Oct.	4 Dec	
5	1 Jan.	6 Feb.	10 Mar.	17 Apl	15 June	14 Sept.	29 Oct.	4 Dec.	
6	12 Jan.	16 Feb.	20 Mar.	28 Apl.	16 June	13 Sept.	27 Oct.	3 Dec.	30 Dec.
7	14 Jan.	18 Feb.	23 Mar.	29 Apl.	16 June	13 Sept.	28 Oct.	3 Dec.	29 Dec.
8	16 Jan.	20 Feb.	25 Mar.	17 Apl.	29 June	13 Sept.	29 Oct.	27 Nov.	22 Dec.
9	23 Jan.	23 Feb.	5 Apl.	14 June	30 Aug.	12 Oct.	16 Nov.	15 Dec.	
10	26 Jan.	26 Feb.	6 Apl.	14 June	30 Aug.	8 Oct.	16 Nov.	14 Dec.	
11	28 Jan.	5 Mar.	6 Apl.	14 June	30 Aug.	8 Oct.	16 Nov.	13 Dec.	
12	1 Feb.	6 Mar.	12 Apl.	14 June	30 Aug.	12 Oct.	23 Nov.	19 Dec.	
13	4 Feb.	9 Mar.	12 Apl.	15 June	7 Sept.	12 Oct.	23 Nov.	18 Dec.	
14	21 Jan.	3 Mar.	14 Apl.	15 June	7 Sept.	18 Oct.	24 Nov.	20 Dec.	
15	18 Jan	1 Mar.	14 Apl.	15 June	7 Sept.	18 Oct.	24 Nov.	21 Dec.	
16	20 Jan.	25 Feb.	27 Mar.	17 Mar.	29 June	28 Sept	28 Oct.	27 Nov.	22 Dec.

Waterings—1909.

No. of Plot.	1st.	2nd.	3rd.	4th.	5th.	6th.	7th.	8th.	9th.
1	15 Jan.	13 Feb.	24 Mar.	6 Dec.	31 Dec.				
2	13 Jan.	12 Feb.	24 Mar.	3 Dec.	31 Dec.				
3	6 Jan.	11 Feb.	12 Mar.	4 Dec.	30 Dec.				
4	6 Jan.	26 Jan.	18 Feb.	15 Mar.	3 Dec.	29 Dec.			
5	4 Jan.	25 Jan.	18 Feb.	15 Mar.	2 Dec.	29 Dec.			
6	6 Jan.	13 Jan.	30 Jan.	16 Feb.	11 Mar.	6 Dec.			
7	15 Jan.	17 Feb.	4 Dec.						
8	16 Jan.	22 Feb.	9 Mar.	2 Dec.	29 Dec.				
9	18 Jan.	2 Feb.	24 Feb.	26 Nov.	18 Dec.				
10	21 Jan.	8 Feb.	2 Mar.	26 Nov.	18 Dec.				
11	21 Jan.	17 Feb.	26 Nov.	20 Dec.					
12	18 Jan.	8 Feb.	8 Mar.	26 Nov.	20 Dec.				
13	18 Jan.	4 Feb.	9 Mar.	27 Nov.	20 Dec.				
14	6 Jan.	29 Jan.	27 Mar.	27 Nov.	21 Dec.				
15	22 Jan.	17 Feb.	27 Nov.	28 Dec.					
16	22 Jan.	16 Feb.	2 Dec.	29 Dec.					

Cuttings—1910.

1	15 Jan.	10 Feb.	19 Mar.	2 May	11 July	9 Sept.	12 Nov.	12 Dec.	
2	8 Jan.	10 Feb.	19 Mar.	2 May	11 July	9 Sept.	12 Nov.	12 Dec.	
3	6 Jan.	9 Feb.	19 Mar.	2 May	11 July	9 Sept.	12 Nov.	12 Dec.	
4	4 Jan.	7 Feb.	14 Mar.	2 May	11 July	9 Sept.	11 Nov.	12 Dec.	
5	3 Jan.	7 Feb.	14 Mar.	2 May	18 June	9 Sept.	11 Nov.	17 Dec.	
6	31 Jan.	28 Feb.	20 Apl.	18 June	18 Sept.	10 Nov.	9 Dec.		
7	31 Jan.	26 Feb.	20 Apl.	15 June	1 Sept.	10 Nov.	9 Dec.		
8	24 Jan.	26 Feb.	20 Apl.	15 June	31 Aug.	9 Nov.	8 Dec.		
9	17 Jan.	19 Feb.	29 Mar.	25 May	27 Aug.	7 Nov.	6 Dec.		
10	17 Jan.	19 Feb.	29 Mar.	25 May	27 Aug.	27 Oct.	6 Dec.		
11	14 Jan.	17 Feb.	29 Mar.	25 May	27 Aug.	27 Oct.	6 Dec.		
12	20 Jan.	21 Feb.	5 Apl.	10 June	27 Aug.	7 Nov.	6 Dec.		
13	20 Jan.	21 Feb.	11 Apl.	10 June	27 Aug.	7 Nov.	6 Dec.		
14	22 Jan.	23 Feb.	11 Apl.	13 June	27 Aug.	8 Nov.	6 Dec.		
15	22 Jan.	23 Feb.	11 Apl.	13 June	27 Aug.	8 Nov.	6 Dec.		
16	24 Jan.	25 Feb.	20 Apl.	15 June	31 Aug.	9 Nov.	8 Dec.		

Waterings—1910.

1	22 Jan.	5 Mar.	25 Nov.	31 Dec.					
2	28 Jan.	6 Mar.	8 Apl.	28 Nov.					
3	1 Feb.	7 Mar.	8 Apl.	28 Nov.					
4	1 Feb.	7 Mar.	8 Apl.	28 Nov.					
5	29 Jan.	7 Mar.	9 Apl.	29 Nov.					
6	6 Jan.	28 Jan.	10 Mar.	7 Apl.	30 Nov.				
7	3 Jan.	28 Jan.	10 Mar.	7 Apl.	2 Dec.	31 Dec.			
8	26 Jan.	9 Mar.	7 Apl.	3 Dec.	31 Dec.				
9	19 Jan.	25 Feb.	6 Apl.	3 Dec.	22 Dec.				
10	19 Jan	26 Feb	6 Apl.	25 Nov.	21 Dec.				
11	12 Jan.	26 Feb.	21 Mar.	6 Apl.	24 Nov.	19 Dec.			
12	25 Jan.	26 Feb.	2 Apl.	5 Dec.	23 Dec.				
13	26 Jan.	2 Mar.	2 Apl.	5 Dec.	27 Dec.				
14	26 Jan.	8 Mar.	5 Apl.	6 Dec.	28 Dec.				
15	26 Jan.	9 Mar.	5 Apl.	7 Dec.	29 Dec.				
16	26 Jan.	3 Mar.	4 Apl.	3 Dec.	30 Dec.				

MARKETING LUCERNE.

The practice of growing lucerne for sale only is not sound farming; live-stock farming should be followed if possible.

LUCERNE FOR ENSILAGE.

Lucerne by itself does not, as a rule, make satisfactory ensilage, but, combined with other fodders which tone down the disagreeable odour developed in the silage, it is a complete success.

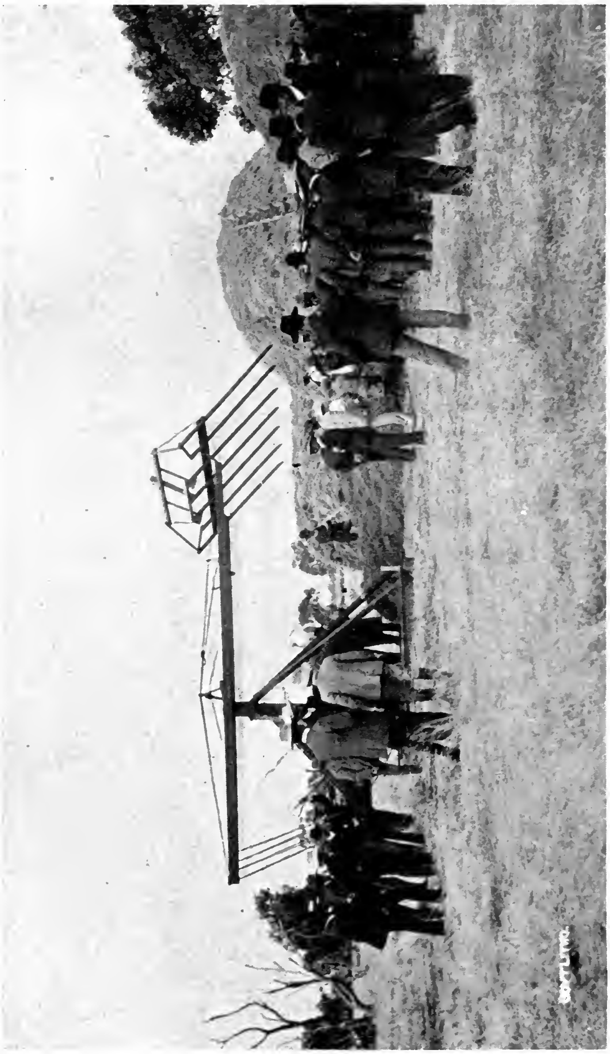


Fig. 42.—Harvesting and Stacking Lucerne.

There are two periods at which this can be economically carried out. The first crop of lucerne is often dirty with weeds and is also more difficult to cure as hay, the weather being then uncertain. In a good spring, too, there is surplus grass about paddocks and this with such plants as wild oats, barley grass, etc., which are very little good as fodder, can be converted into ensilage with great advantage.

Again, in the autumn, the last cut of lucerne, if woody, can be mixed with maize to the advantage of both; in the proportion of about half and half this makes a first class silage. Lucerne for ensilage is cut at the same time and stage as for hay, but is carted straight into the silo unless wet with rain (Fig. 43).

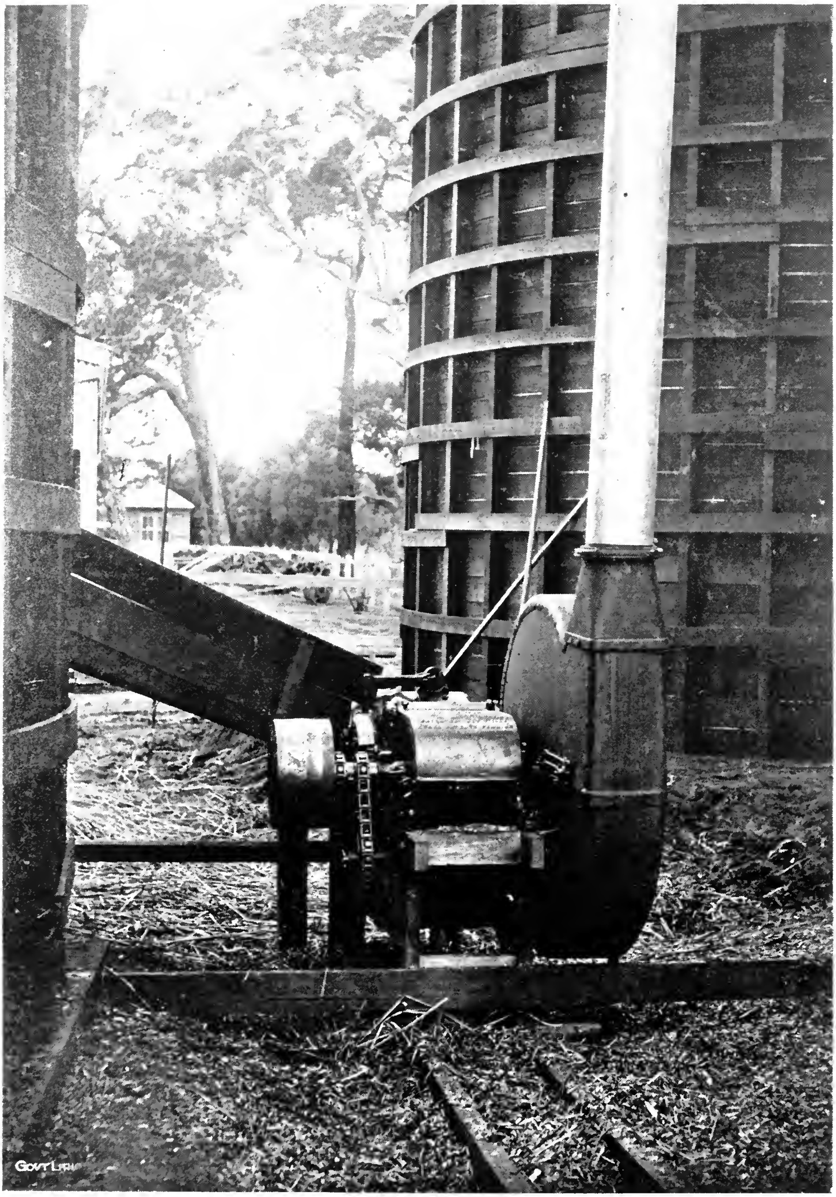


Fig. 43.—Jarrah Tub Silos and Ensilage Cutter, equipped with Blower Elevator, Brunswick State Farm.

It must be understood that where the crop is clean and the weather favourable lucerne will give much better results when turned into hay. (*See* Fig. 44.)

SOME LUCERNE "MUSTS" AND "DON'TS."

First of all the seed must be pure and of high germinating power.

The soil must have lime—either as one of its natural constituents, or lime must be added.

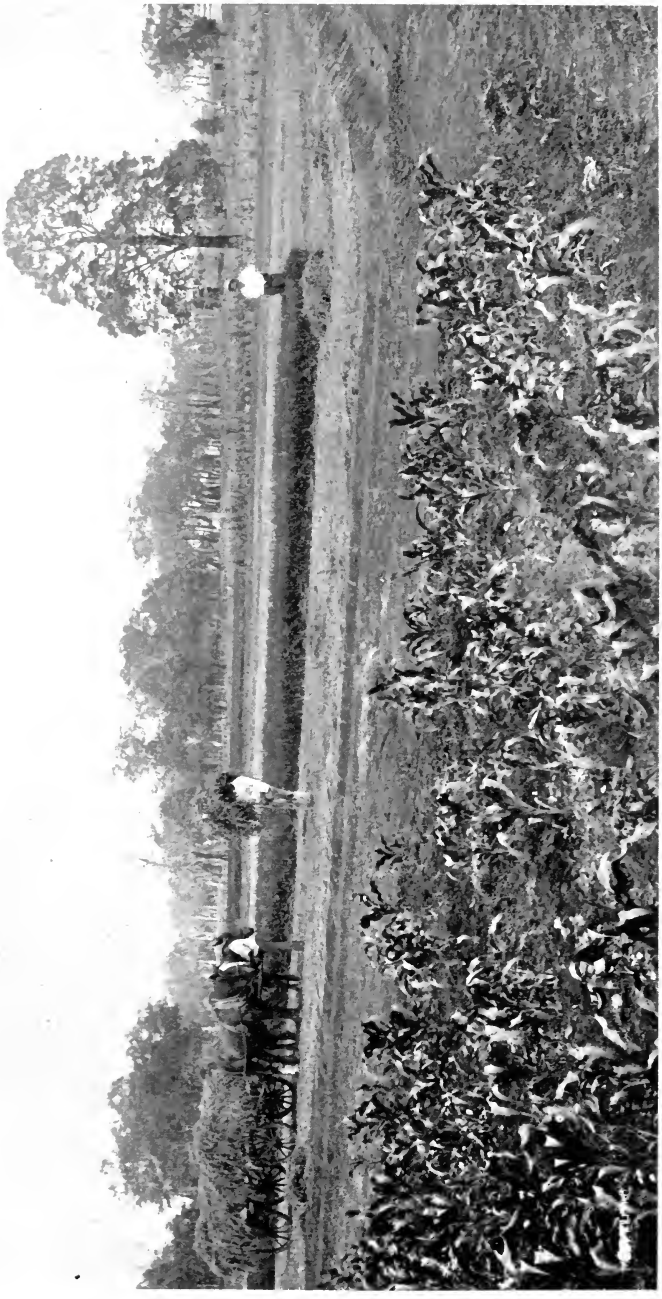


Fig. 44.—Lucerne under Irrigation, 26 days from last cutting. Young Maize in foreground, S.W. District.

The land must have efficient drainage.
The land must be fertile to a depth of at least nine inches.

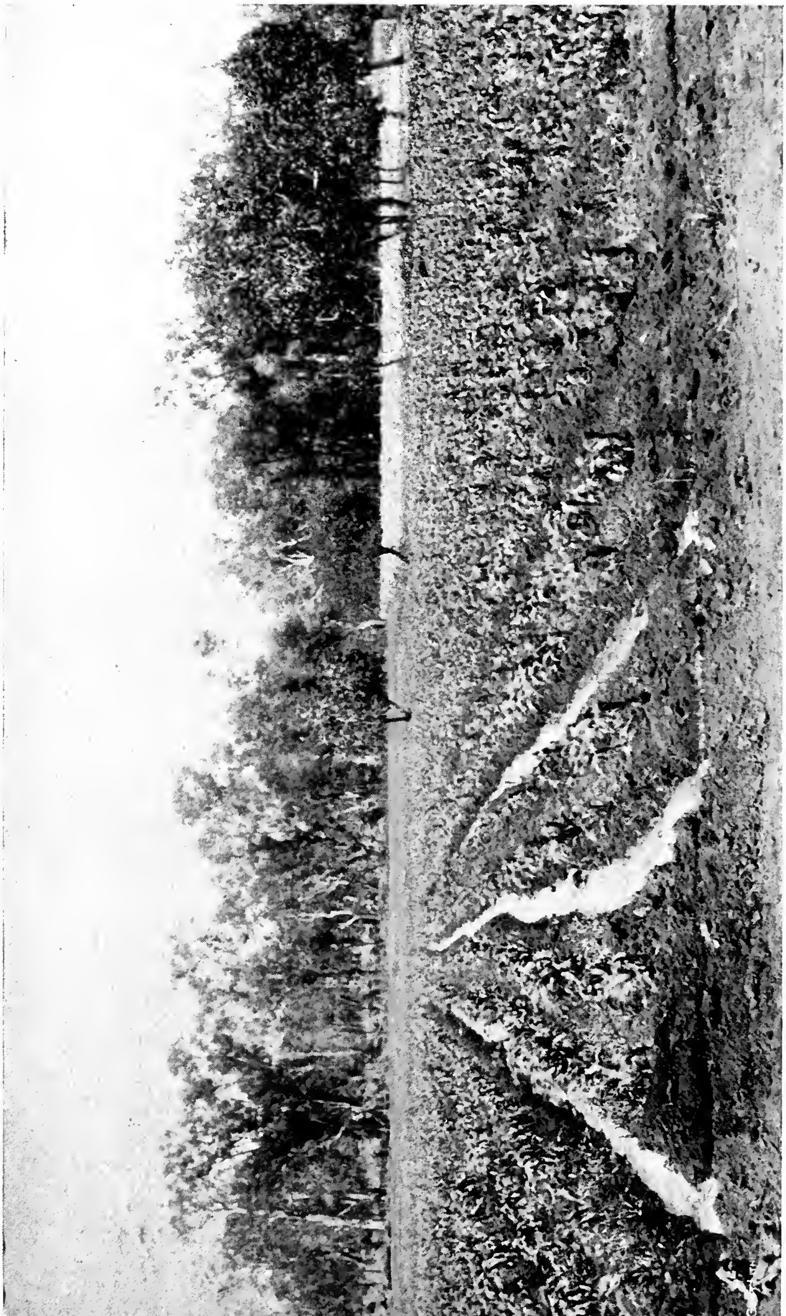


Fig. 45.—Young Maize, showing system of Planting and Irrigating, W.A.

Don't sow any nurse crop.
Don't sow on new ground, no matter how carefully prepared.

Don't let weeds grow over six inches high without mowing.
Don't let lucerne stand; if turning yellow cut it.

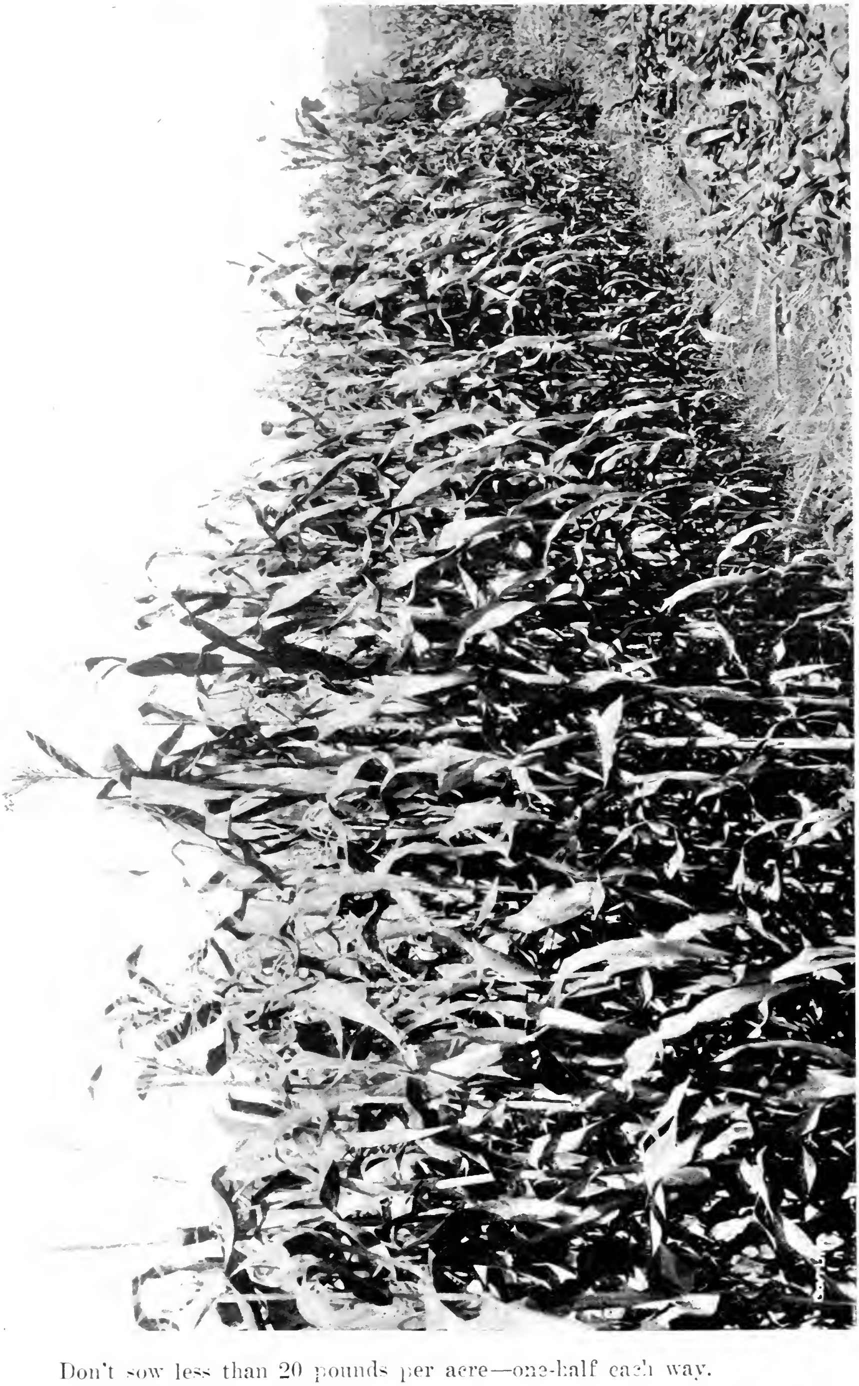


Fig. 46.—Irrigated Maize—Furrow System, W.A.

Don't sow less than 20 pounds per acre—one-half each way.
Don't sow 25 acres at first; sow five.

Don't pasture it.
Don't let any water stand on it.
Don't give up.

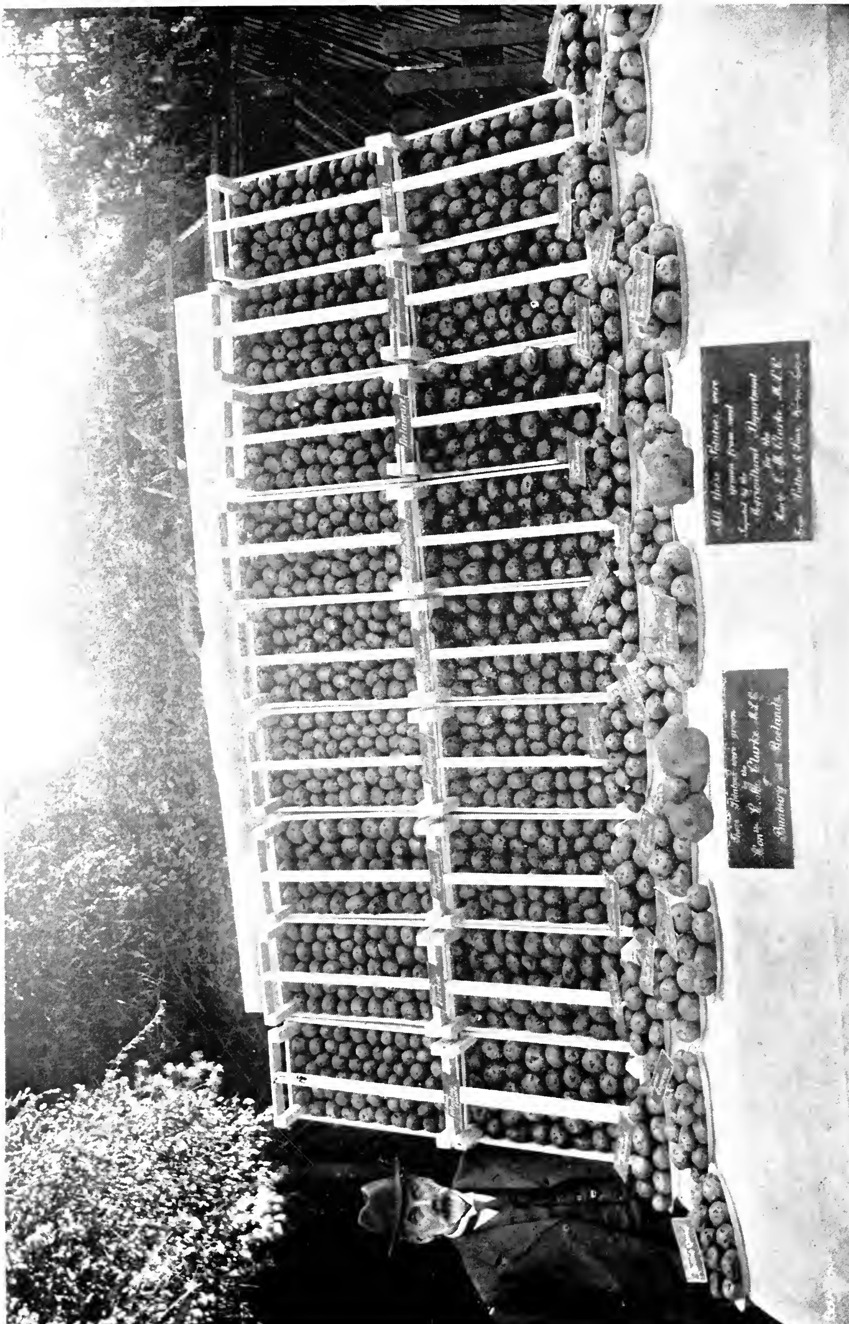


Fig. 47.—Potatoes grown under Irrigation.

MAIZE AND SORGHUM UNDER IRRIGATION.

Maize should be planted more extensively in our South-West. It is best sown in drills about three to four feet apart and irrigated between. (*See* Figs. 45 and

46.) The ground must be moist as if the seed is sown in dry soil, and then irrigated, much will fail to germinate.

Even in fairly moist soils I always take the precaution of running the water down the open furrows before sowing.

Again, sorghum is an excellent fodder and will give from one to three cuts from one planting. The first crop often grows to a height of 10 or more feet. Crops should be usually cut when in flower; it is injurious to stock during the early stages of growth, but can be safely fed to animals when mature.

POTATOES UNDER IRRIGATION.

Potatoes raised under irrigation have not always earned a very desirable reputation for quality, but I claim, by intelligent cultivation, that this trouble can be entirely avoided. Potatoes grown on old lucerne fields return immense yields of

Fig. 48.—Engine and Centrifugal Pumping Plant on Preston River.

high quality, as the land is rich in available plant food. The secret in raising irrigated potatoes is to keep the plant growing vigorously, from the time the seed is put into the ground until the crop is matured. Apply just as little water as is practicable, and under no circumstances allow the water to touch the haulms. A heavy flooding of the field before planting is advisable, and, in some cases, this watering has been known to mature the crop without a further application. The Hon. E. M. Clarke, M.L.C., of Roelands, near Bunbury, has produced some fine irrigated crops of potatoes, and a visit to his farm will be fully repaid by anyone interested (Fig. 47).

IRRIGATION POWER PLANTS.

When water is to be raised by motive power the question of cost is of vital importance—not so much the first cost as the cost of running.

When small power is required oil engines (Fig. 48) have been found very satisfactory—more so than the steam engine, because the latter requires the constant attention of a certificated driver, whereas the oil engine can be left for seven

Fig. 49.—Discharge Basin, and Regulating Bulk-head in distance, W.A.

or eight hours at a stretch, thus enabling the small irrigator to attend to the work himself.

Where, however, large quantities of water have to be raised a considerable height, the suction gas engine and plant is invaluable.

Erect your plant as near the actual water supply as is consistent with safety and economy.

Be sure your foundations are solid and permanent

PIPES AND CENTRIFUGAL PUMPS FOR IRRIGATION.

For lifting a large quantity of water to a moderate height no form of pump surpasses the centrifugal. Centrifugal pumps also possess the advantage of strength and simplicity of construction; they are moderate in first cost, require little foundation, and are easily erected and repaired.

Where applicable it is by far the best pump for irrigation and drainage purposes, as it is readily erected in awkward positions and, having no valves, it is especially adapted for raising water containing foreign matter. It will pass gravel, sand, leaves, etc., which would very soon choke ordinary forms of pump.

The working parts of the pump consist, briefly, of a series of curved blades or discs, mounted on a spindle, and made to revolve in a cast-iron case, somewhat similar to a fan-blower. The revolution of these blades produces a partial vacuum in the case which, aided by the pressure of the atmosphere, brings up the water. The pump should be placed as near the water as practicable.

When pumping from rivers, creeks, etc., it is customary to have the engine and pumps placed at right angles to the stream. It is imperative to have all the pipe joints on the suction side of pump air-tight.

All pipes should have a clear waterway at least equal in area to the suction and discharge branches on pump. In pipes with large rivet-head flanges projecting inwards, the area of pipe is greatly reduced and impedes the flow of water. Due allowance must be made for such obstructions. Pipes of large diameter are always to be recommended, and more especially where a considerable length of piping is required. Every care must be taken to prevent the joints between pipe flanges projecting into waterway pipes, and to guard against air traps being formed in the pipes and pump, as such defects may even prevent the pump from discharging any water. Use as few bends as possible and never use a short right angle bend. Insist upon long bends or springs wherever they are necessary.

To prevent washing of the soil at the point where the pump discharges into the channel it is always necessary to form a sump or basin. This can be constructed of either brick, stone, cement, or, in some cases, an iron tank can be utilised. Fig. 49 shows a discharge basin formed with bricks laid without cement or mortar.

The use of light flanged galvanized piping will be found very economical in many cases. For 8 or 10 inch pipes 16 gauge should be used, but for 5 or 6 inch pipes 18 gauge will be found sufficiently strong. Owing to the demand for this class of pipe for irrigation purposes a plant for their manufacture has just been erected in this State.

Wood pipes have come greatly into vogue during the past ten years, especially in America where suitable wood is easily obtainable. So far, however, they have not been extensively used in this State.

Galvanized iron fluming (Fig. 50) is often used for conveying water across depressions and is sometimes utilised for head ditches, small openings being provided at intervals for distributing water. A useful size will be found about 20 inches wide by 9 inches deep.

Wooden fluming has been used to a certain extent in Western Australia, but practice has demonstrated that our native timbers are not suited to this class of work.

WINDMILLS.

The use of windmills for pumping water is to be recommended wherever a small supply of water exists, but their usefulness for irrigation purposes is naturally limited by the wind. It is always necessary to provide large tanks or storage reservoirs if irrigation is proposed to be undertaken. We have many examples in this State of small areas being watered by windmill power, but, as a rule, the mills

Fig. 50.—Flume and Ditch in Vineyard, Upper Swan, W.A.

are far too small to perform effective work. In the United States of America and Canada I have seen splendid small irrigation systems using large windmills (diameter of fan-wheel from 20 to 30 feet) as power.

General conditions in these two countries are similar to many parts of our South-West, and the idea could be copied by our farmers with advantage.

HYDRAULIC RAMS.

These will often prove extremely useful and economical for raising water where a sufficient fall is available. The principle on which it works is that a larger volume of water having a certain fall will force, under certain conditions, a smaller volume of water to a higher point than itself. In estimating the amount of water that can be raised and discharged, a general rule is to calculate that about one-seventh of the water used can be raised and discharged at a height five times as high as the fall.

Hydraulic rams will work without interruption day and night and require no attention or expense except for the renewal of valves—say, once every year or two—which is trifling, as they cost but little.

Fig. 51.—The end of the day.

USEFUL INFORMATION.

1. A cubic foot of water contains 6.24 British Imperial gallons—approximately $6\frac{1}{4}$—therefore 27 cubic feet (or 1 cubic yard) contains $168\frac{1}{2}$ gallons.

2. A cubic foot of water (U.S.A. measure) contains $7\frac{1}{2}$ gallons, and when reading American publications allowance must always be made for this difference.

3. One gallon of water weighs 10lbs.

4. One acre of land covered with water to a depth of one inch equals 22,624 gallons.

5. The term "acre-foot" is the amount of water it takes to cover an acre of land to a depth of 12 inches. (261,488 gallons.)

6. Doubling the diameter of a pipe increases its capacity four times.

7. The length, breadth, and height of a cistern multiplied together, in feet, and the product multiplied by $6\frac{1}{4}$ will give the capacity in gallons.

8. Capacity of circular cisterns one foot in depth:—

Diameter.	Capacity.
5 feet	$122\frac{1}{2}$ gals.
6 ,, ...	$176\frac{1}{2}$,,
7 ,, ...	$240\frac{1}{2}$,,
8 ,, ...	314 ,,

POINTS RELATING TO HORSE POWER.

One Horse Power is the power required to lift 33,000lbs. one foot, or one pound 33,000 feet per minute.

The Brake Horse Power (B.H.P.) of an engine is the actual power given off at the belt or shaft, or by the fly-wheel and is variously called "Effective," "Actual," "Belt," and Brake Horse Power.

The Indicated Horse Power is the power given off by the piston in the cylinders from which the friction of the piston and other working parts of the engine have to be deducted before the B.H.P. is arrived at.

The Nominal Horse Power is a commercial term which most makers still use for steam engines. As a rough guide it may be taken that a 6 Nominal H.P. Steam Engine at 60lbs. pressure would be approximately equal to a 12 B.H.P. Oil Engine.

DRAINAGE.

In the early history of under drainage, drains were made by laying bundles of twigs or brush in the ditches and covering these with earth, the water being expected to trickle through the passage-ways left. In other cases three or four round poles, or two slabs with convex sides, were laid together and placed in the ditch and covered. Sometimes boards were set on edge in the form of an inverted trough. All these devices, however, were temporary, and were of service only as long as the wood remained sound.

More permanent under-drains were later made by filling the bottom of the ditch with small stones, by setting flat stones on edge in a "V"-shape, or else by using three or four stones and building a rectangular-shaped waterway. Bricks were sometimes used in place of stone. Many of these early stone drains, which were properly made, have lasted a long time, and have done good service, but their construction, at the present time, has been largely superseded by the use of drain tiles.

Concerning stone-drains attention may properly be called to the fact that (contrary to the general opinion of farmers) they are more expensive than tile-drains. So great is the cost of cutting the ditches to the larger size required for stone than for tiles, of handling the stones, of placing them properly in the ditches, and of covering them after they are laid, that, as a mere question of first cost, it is cheaper to buy tiles than to use stones, although these may lie on the surface of the field. If the land is stony it must be cleared. This is a proposition by itself, but if the sole object is to make good drains the best material should be used, and this material is not stone. It is supposed that pipe tiles were first used for drains in France about 1600.

EFFECTS OF DRAINAGE.

The first, and one of the most obvious effects of drainage is to rid the soil of its surplus water. Plants need moist ground, but they cannot grow if the soil is too wet.

Roots of plants require air, and soils are better ventilated by means of drainage. When almost all crevices in the soil are filled with water, it will be recognised that air is excluded. Drainage increases the room which roots may occupy. Many of our cultivated plants will naturally send their roots down two or three feet in the soil. If the surplus water has not been removed to this depth the roots will be forced to make a shallow growth, and will be unable to utilise the full resources of the soil. Drainage will so lower the ground water that roots may penetrate to their normal depth.

Another very important effect of drainage is that the soil is made warmer. It is a well known fact that the process of evaporation uses up heat. It will be

readily understood, therefore, that, owing to the excessive evaporation set up in over-wet soils, the temperature must be lowered to a lesser or greater degree. Experiments have shown that the surface of a soil well drained is 3deg. to 12deg. warmer than the same soil undrained. This difference in temperature will very materially hasten the germination of seed. A drained soil can always be worked a few days earlier than an undrained soil—especially after heavy rains.

Again, the effect of drainage increases the available soil moisture. On first thought one would say that the amount of soil moisture would be lessened, but let us see. Strange as this may at first appear it seems quite natural on second thought, for there is more room for water, more pore space in the drained soil.

Two things prevent rain from sinking rapidly into undrained soil, viz.:—

(1.) The scarcity of pore space; and

(2.) The air, escaping upwards—and there is no other outlet for it—half the surface pores must be full of escaping air, while the other half are full of descending water.

In drained soil the air can and does escape downwards through the drains as the water presses from above, and thus all the surface pores, instead of half, are absorbing water, and apart from this, the pores are larger than is the case with undrained land. It follows, then, quite naturally, that drained land must absorb water much faster than undrained.

Now the upper layers of the soil where the roots feed are not capable of storing enough water for the crops, but deeper down in the soil, three, four, five, and six feet, there are large quantities of water which travel slowly upwards and gradually reach the roots. To some this may seem a new idea, and more or less doubt may be aroused. Let the doubter take a lamp chimney, lay a piece of cheese cloth over one end, invert it, fill it with dry earth, and set it in shallow water. He will see the water travel upwards through the soil as tea travels upwards through a lump of sugar, or water through a sponge. This movement of liquid upwards, or otherwise, through porous bodies is known as capillary action or capillarity.

Liquids move downward by the same process, as well as by the more rapid action of gravity, and, when a soil has been saturated and all the water that will has drained away, it is this same power of capillarity that holds a large amount still in the soil.

Where possible, surface and soil water should be intercepted before entering a farm rather than drained from it. This can be done if the drain is so located as to intercept the natural underflow.

DEPTH AND DISTANCE APART OF DRAINS.

The depth at which drains should be placed depends largely upon two conditions, viz.:—

(1.) The nature of the soil; and

(2.) The average distance of the ground watertable below the surface.

Generally speaking, four feet is considered deep drainage, three feet medium, and two feet to two feet six inches shallow. There is a close relationship between the depth and distance apart of drains. The distance apart will largely depend upon the depth. In heavy retentive clay soils it is advisable to lay the tiles between medium and shallow, for two reasons—

(1.) Because the water filters through them so slowly that it takes a long time to reach the drains;

(2.) Because the cost of digging increases very rapidly with the depth in a hard clay soil.

In a more porous, loamy soil, experience has shown that the most practical depth is about three feet.

The second condition mentioned above—which affects the depth—is important in this respect as the level of the ground water changes with the season, and is usually highest in the early spring. If the ground water then comes too near the surface in the spring it may be desirable to lay the drains only deep enough to dry the land for ploughing and cultivation at the proper time. Shallow drainage will usually suffice where this condition of affairs is to be met. On the other hand, when the ground water is not sufficiently low at any season of the year for the maximum development of the roots, it is best to resort to deep drainage, and unless the soil is a retentive clay the trees may be placed from three and one-half to four feet deep.

The distance between drains must be determined by—

(1.) The character of the sub-soil which naturally controls the rate at which the water moves towards the drains.

(2.) The rainfall.

(3.) The depth at which the drains are placed.

In common practice tile drains—when regulated by the above-mentioned conditions—can be placed from 30 to 100 feet apart. I have known cases where the drains have been placed 150 feet apart, and have proved highly satisfactory.

SIZE OF TILE AND FALL OF DRAINS.

The size of the main drain will depend upon the fall of the land and the area it is to drain. The greater the fall the smaller the tile. If the fall is doubled the carrying capacity is increased about one-third. A 4-inch main will suffice for most ordinary systems where the area to be drained does not exceed 10 or 12 acres.

If 20 or 30 acres are required to be drained into one main it should be 5 to 6 inches in diameter. For laterals a 3-inch tile will usually be found satisfactory. The danger in using smaller tiles lies in the fact that it does not take a great deal of sediment to fill them, and unless laid on a true grade with a good fall their efficiency will soon diminish. A variation of an inch below a true grade will result in filling a 2-inch tile just half-full of sediment, while an inch of sediment in a 3-inch tile will only reduce its carrying capacity about one-fourth. I have dug up 2-inch tiles, with only a slight fall, which were so full of sediment as to be rendered practically useless.

Errors resulting from using a tile which is too small are most serious, and the only safe plan is to be sure the tile is large enough even though the initial cost is somewhat greater.

Practical experience has shown that it is better in our heavy rainfall districts to use a 3-inch drainage tile instead of the 2-inch. Hereunder I give an estimate—per chain—of constructing 2-inch, 3-inch, and 4-inch tile drains, at a distance of 160 miles from Perth:—

Cost of Tile Drainage at a depth of 2ft. 6in. to 3ft.

	£	s.	d.
Cost of 2in. tiles per 1,000	3	5	0
Freight per 1,000 at 8s. 4d. per ton (1 ton 6cwt.) ..	0	10	10
Cartage at 5s. per ton	0	6	6
Total cost per 1,000	£4	2	4
Cost per chain	0	5	5
Cost of labour per chain	0	9	0
Total cost per chain	£0	14	5

Cost of 3in. tiles per 1,000	5	5	0
Freight per 1,000 at 8s. 4d. per ton (2 tons 9cwt.) ..	1	0	5
Cartage at 5s. per ton	0	12	3
Total cost per 1,000	£6	17	8
Cost per chain	0	9	1
Cost of labour per chain	0	9	0
Total cost per chain	£0	18	1
Cost of 4in. tiles per 1,000	7	10	0
Freight per 1,000 at 8s. 4d. per ton (4 tons)	1	13	4
Cartage at 5s. per ton	1	0	0
Total cost per 1,000	£10	3	4
Cost per chain	0	13	5
Cost of labour per chain	0	9	0
Total cost per chain	£1	2	5

With regard to the fall of a drain it is advisable to have all the fall possible. It is important, if obtainable, that the fall should be uniform; *i.e.,* not to change one grade to another in the same line of tile. In changing from a steep to a less steep grade the velocity of the water is checked, and there is danger of sediment being deposited where the change is made. It may be found, in some cases, impossible to avoid this but the difficulty may be overcome by placing a silt basin or box where the change of grade occurs.

Of course there is no objection to changing from a small grade to a greater one, for in this case the velocity will be increased and the sediment will be carried onward.

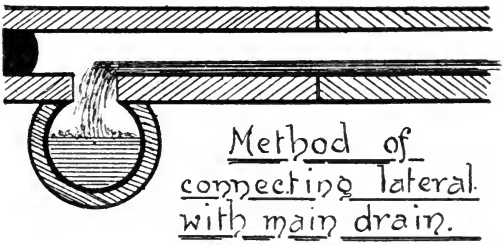


Fig. 52.

Where laterals connect with the main drain carry the branch above the top of the main (Fig. 52). Cut a hole on the top of the main and the bottom of the end tile of the lateral, placing the two openings together, but first closing the end of the tile with a stone and clay. This arrangement allows the lateral to empty itself completely into the main and prevents it from becoming clogged with sediment by the setting back of water into it.

In laying pipes we find it is recommended, at times, to place pieces of heavy paper, cloth, or sod over the joints to prevent the washing of dirt into the drain.

These precautions are all very good and, in some cases, may be essential, but in general practice the extra expense will not be found profitable. If paper bark is easily obtainable use it by all means. It can be laid on the tile just as it comes from the tree; no cutting into small strips is necessary. The upper ends of all lines of tile should be carefully closed by placing a flat stone or brick against them. In filling in pack the soil last taken out of the ditch well about the tile.

KIND OF TILE.

A good drain tile should be hard burned, giving a sharp ring when struck. It was formerly thought that tiles should be porous so that the water could freely enter them, but Chamberlain in his "Tile Drainage," cites some very interesting experiments which prove that the porosity of a tile has nothing to do with the water entering it. There is plenty of space at the joints for all water to enter.

To illustrate the importance of this branch of agriculture I might mention that in the United States of America there are over 7,000 factories engaged in turning out tile pipes for drainage.

EXCAVATION OF DRAINS BY MACHINERY.

For excavating large drains Power Ditching machines should be used when possible, as the saving in cost is considerable. Fig. 53 shows an Austin Ditcher at work. This useful machine will cut a ditch, form the slopes, and throw the spoil well away from the ditch edge. It can be converted, by a simple alteration, so as to dig a ditch with vertical sides or a sewer trench. It works very rapidly but this, of course, is governed by the size of the ditch and the character of the soil.

TILE DRAINAGE.

Summary.

1. Pole, slab, and stone drains have been superseded by the tile drain. The use of the tile is becoming more and more extended every year.

2. The effects of tile drainage are that the surplus water is removed from the soil; the soil is better ventilated; roots are given more room; the soil is made warmer, and the available moisture is increased.

3. The size of the tile will depend upon the fall and the area drained. For mains 4-inch and for laterals 3-inch will usually be found most satisfactory and economical.

4. In laying drains have all the fall possible.

5. For clay soils drains should be about two and a-half feet deep and 35 to 50 feet apart. For porous, sandy soils, they may be three and a-half feet deep and 60 to 100 feet apart.

6. Select the lowest ground for the main. Have as few outlets as possible and put in laterals through the wettest places first.

7. If the fall is slight have it accurately determined by a competent man—it will pay you. In other cases the ordinary carpenter's or home-made level may be used.

8. Begin digging at the outlet. Make the ditch just wide enough for a man to work in. Be sure the bottom is properly graded so that no low places are left in it.

9. Round tiles, hard-burned, and free from lime, straight, smooth on the inside, and with ends square cut, are the best.

10. Place very hard-burned tiles next to the outlets.

DRAINAGE OF LARGE AREAS OR DISTRICTS.

The complete drainage of farm lands in our South-Western districts—with its heavy rainfall—can be effected only by the enlargement and general improvement

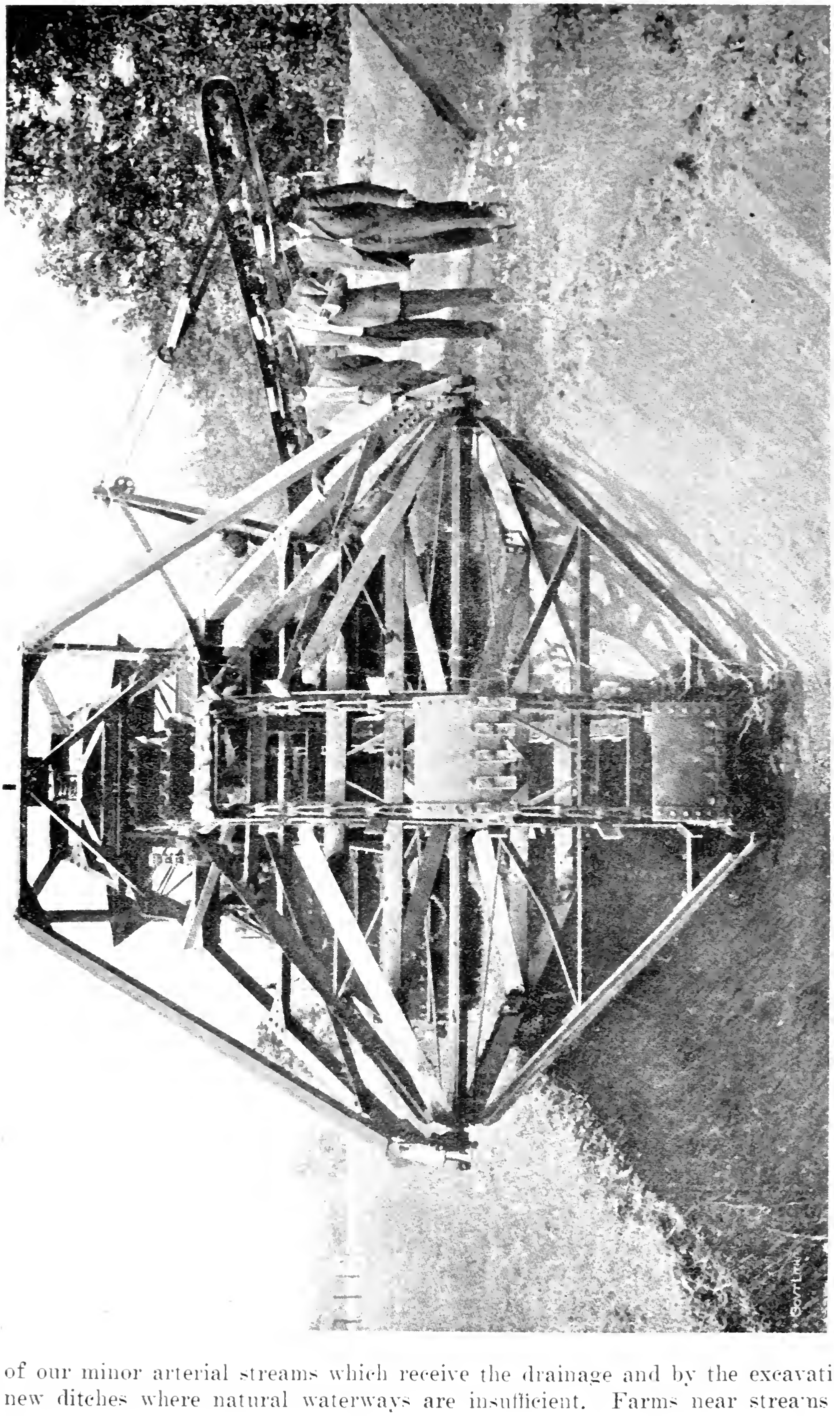


Fig. 53.—Austin Ditching Machine, with Bank Sloping Attachment.

of our minor arterial streams which receive the drainage and by the excavation of new ditches where natural waterways are insufficient. Farms near streams must

be protected from the overflow which periodically endangers them. This must be considered in connection with the more complete improvement of higher lands, the drainage of which contributes to the supply of main streams.

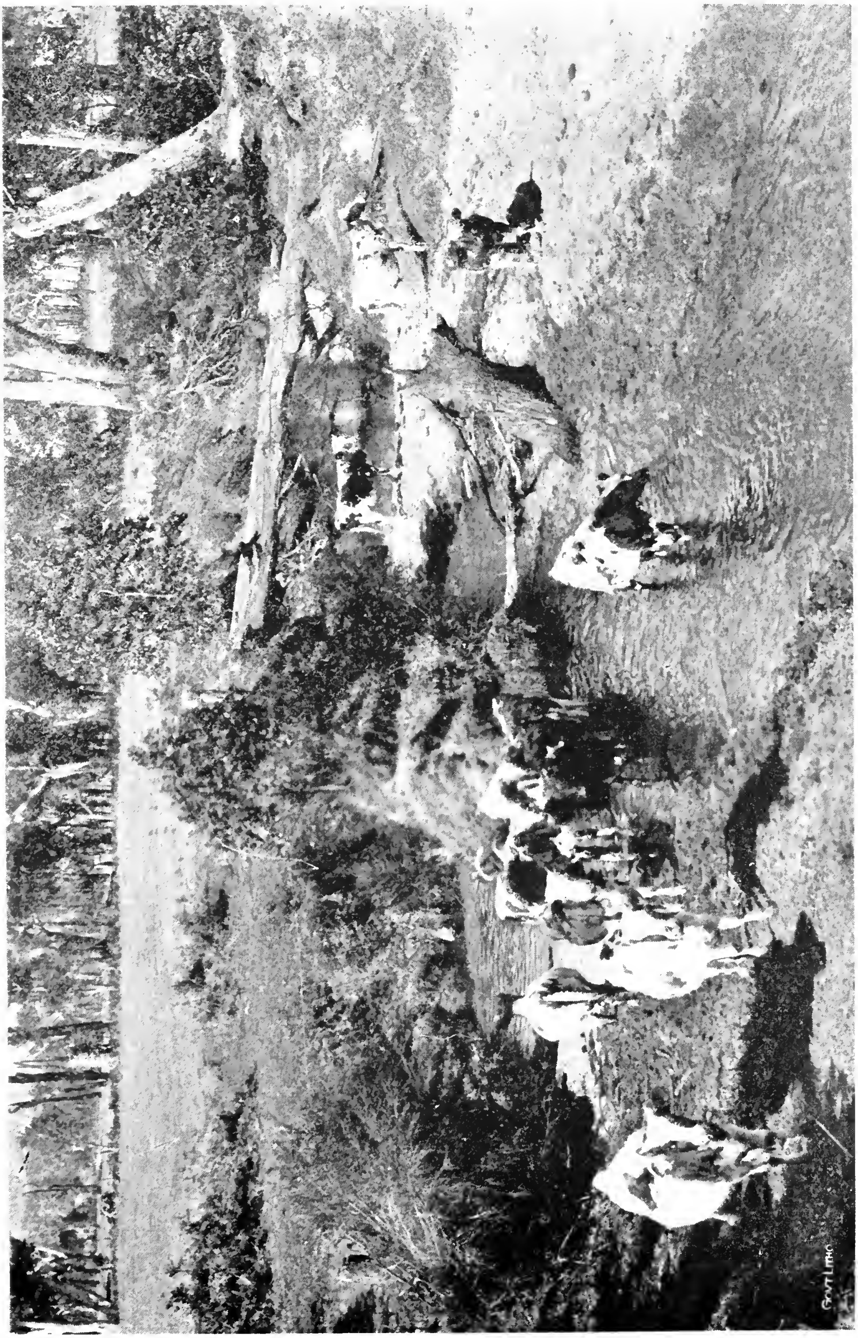


Fig. 54. A river in the South-West during Summer (time of photo). Flow $1\frac{1}{2}$ million gallons per 24 hours.

So many phases of the drainage problem are involved in dealing with a work of this kind that any investigation resolves itself into an examination of individual

cases in which local as well as general difficulties must be considered. The ultimate removal of surplus water during the winter and its utilisation, if possible, during the summer is the end to be sought.

In some of our low-lying lands excellent work has been undertaken both by private individuals and the Government.

Drainage is a permanent improvement and, although the initial cost seems high, its effects are timely and far-reaching.

Fig. 54.—A river in the South-West during summer (time of photo.); flow $1\frac{1}{2}$ million gallons every 24 hours.

IRRIGATION OF LUCERNE.

Reprinted from Farmers' Bulletin 373, U.S. Department of Agriculture.

Experience in the growing of lucerne for more than two thousand years shows that it thrives best in the soil and climate of arid and semi-arid regions. The abundant sunshine, the warmth, and the deep, rich soil prevailing throughout the western half of the United States seem to be well suited to its requirements, and over half a century's experience has shown that there is comparatively little cultivable land in the West on which it cannot be grown. One finds the same varieties flourishing in Imperial Valley, California, 100 feet below sea level, and maintaining a sturdy growth on the San Luis plains of Colorado, 7,500 feet higher. Lucerne makes a remarkable growth in the warm sunshine of Arizona, yet it is rarely injured by cold in Montana.

One cannot well over-estimate the importance of lucerne to western farmers. The lucerne field and the lucerne stack provide the best means of protecting stock against enormous losses by starvation when the excellent pasturage available throughout the greater part of the year fails either through drought in midsummer or by being covered with deep snow in midwinter. A single ton of lucerne may save the lives of many head of stock by providing feed during short periods of cold, stormy weather. Lucerne cannot be excelled as a preparatory crop on soils that have long been unproductive. Likewise, it maintains the fertility of soils naturally rich in plant food, and if used as a base of rotation makes possible abundant crop yields of various kinds. In 1906, the chemist of the Colorado Experiment Station estimated the fertilising value of the stubble and roots of mature plants at £7 per acre when measured by the commercial value of artificial fertilisers on the market. Moreover, the yields are exceptionally high when irrigation, favourable climatic conditions, and proper treatment are combined. Seven tons of cured hay at three cuttings are obtained from the best fields of Montana, while frequently 9 tons in five cuttings are harvested in California. This large tonnage, together with its high feeding value and the fact that it is consumed by practically all farm animals, makes it not only a convenient and useful crop to the grower, but a highly profitable one as well.

Notwithstanding its present importance and great value in irrigation farming, the profits on the area now in lucerne can be greatly increased if more care and skill are exercised in growing it. The western irrigator has seldom been able, financially, to dig his ditches and prepare his fields in such a way as to insure the most efficient irrigation and the highest profits. In consequence, valuable water is wastefully applied to land that is in no fit condition to be irrigated. On the large acreage in irrigated lucerne this amounts to an enormous loss. This fact, considered in connection with the importance of this crop, the rapidly increasing area devoted to its growth, and the large number of farmers who are settling in the West, and who will be for years dependent in a large measure on lucerne for a livelihood, would seem to warrant the collection and publication of any information designed to improve the present practice.

As its title implies, this publication deals with but one feature, that of irrigation, and its scope is necessarily limited to irrigated lands. There has been no attempt to present or discuss at any length other phases of the general subject

of lucerne growing, and wherever mention has been made of these it has been only to show their relationship to irrigation.

In the examination of lucerne fields and the collection of the data necessary for this publication, advantage was taken of the organisation of the irrigation investigations of this Office, which is well adapted for such a purpose. Through the State and Territorial agencies of that division, and through co-operation with the members of the State experiment stations and the State engineers, it was possible to obtain with a high degree of accuracy the conditions and irrigation practice with reference to this crop throughout the entire arid region.

Irrigable Lands Adapted to Lucerne.

Perhaps the most essential conditions for the production of lucerne are abundant sunshine, a high summer temperature, sufficient moisture, and a rich deep, well-drained soil. All of these essentials, save moisture, exist naturally in the arid region of the United States, and when water is supplied it makes the conditions ideal. Although lucerne can be successfully grown under a wide range of soil conditions, yet all western lands are not equally well adapted to its growth. For this reason those who are seeking such lands with a view to their purchase should first make a careful examination of the character and depth of the soil, its behaviour when irrigated, the slope and evenness of the surface, the presence of injurious salts, and the facilities for drainage.

The most favorable condition for irrigating is a smooth surface, with a uniform slope of 10 to 20 feet to the mile. Such land costs little to put into shape for the spreading of water over it, and the slope insures good drainage. Sometimes the land is cut up by ravines, which increase the labour and cost of putting water upon it, or it may have too much or too little slope. In other cases it is full of buffalo or hog wallows, which are difficult to bring to an even grade. If land which is naturally smooth on the surface and of the right slope costs £1 per acre to prepare for irrigating, hog-wallow land may cost £3. Besides, some hog-wallow land is inferior in quality, frequently being charged with injurious salts.

Lastly, good drainage is essential for a permanently productive irrigated farm. It is practically impossible to supply crops with sufficient water for the best growth without applying so much that some will seep into the subsoil. Unless this can flow away, the level of the ground water will rise until it comes near the surface and drowns out crops, and perhaps cause an accumulation of alkali. If the natural drainage is not good, it must be supplied artificially, but this need not be done until a few crops have been raised, for the reason that it is not possible to tell until after irrigation where the drains should be placed to drain the land most effectively.

The frequent failure to get a good stand of lucerne in the humid portions of the United States have led some writers on this subject to prescribe within somewhat narrow limits where and under what conditions this forage plant can be grown successfully. That this view is not correct as regards the irrigated portion of the United States is amply shown by the fact that it is grown successfully in every State and Territory of the arid region, in localities which are not only widely separated but possess many radical differences in the way of rainfall, temperature, altitude, topography, and soil.

Preparatory Crop.

Experience has shown that it is difficult in the course of six months or a year to secure a good stand of lucerne on raw land that has been covered by a desert growth. This is true particularly of rough, uneven land on which crop rotation is not to be practised. It is likewise true of land thickly covered with

brush. It has been found impracticable in most localities to secure a smooth, well-graded surface where fresh roots interfere with the proper use of all grading and levelling implements. The same is true of hog-wallow land, where considerable soil has to be removed from the high places and deposited in the low places. It takes time and a second preparation of the surface before fields of this character can be put in good condition for the growth and irrigation of lucerne. If crop rotation is to be followed, the necessity for a preparatory crop is not so urgent, since the lucerne will soon be ploughed under to give place to another crop. In northern Colorado, where lucerne usually follows either potatoes or sugar beets, the surface is not ploughed, but merely harrowed or disked in the spring just before seeding. If the surface is uneven, it is smoothed and levelled by means of a float or drag before the seed is put in. In southwestern Kansas it is likewise considered best to plant lucerne after some cultivated crop which has held the weeds in check. The land is ploughed in the fall to a depth of 6 inches, double-disked in the spring after the weeds have started, and is subsequently harrowed. In the vicinity of Los Banos, Cal., new land is almost invariably sown to barley or corn for two seasons before seeding to lucerne. In Utah, wheat or oats is preferred as a preparatory crop. The chief purpose of all such preparatory grain crops is to allow fresh roots of the original plant covering to decay, filled-in spots to settle, high places denuded of the upper layer of soil to weather, and in general to prepare a well-pulverised seed bed in a smooth, well-graded field.

Methods of Irrigating Lucerne.

The methods of applying water to lucerne differ widely because of diversity in soils and subsoils, in climate, and topography, in the nature of the water supply, the size of the farm, the amount of money available for preparing the land for water, the prevailing crops grown, and the early training and environment of the irrigator. The standard methods have been grouped under the following heads, namely, the border method, the check method, flooding from field laterals, furrow irrigation, and other less common methods, with various modifications of each.

In passing, it may be said that the usual order is to locate and build the farm ditches first and prepare the land afterwards. In this bulletin it has been deemed best to describe the methods in use and then to consider the location and construction of farm ditches. After one has a general knowledge of the various ways of applying water, and of the size and character of the ditches required for each method, he is in a better position to understand the proper methods to adopt in building farm ditches. This subject will, therefore, be treated separately under its own heading.

The Border Method.

Essentially, the border method consists of the division of a field or tract into long, narrow strips, or lands by low flat levees, which usually extend in the direction of the steepest slope and confine the water to a single strip. The bed of each strip is carefully graded to a uniform slope, although the slope may change to conform to the contour of the natural surface. The water to irrigate each strip is taken from the head ditch extending across the upper edge of the field, and is controlled by an outlet box or border gate, although the gates are sometimes omitted to save in first cost of preparing for irrigation. Check gates, canvas dams, or metal tappons are used to hold up the water in the head ditch to cause it to flow into the borders.

This method is confined chiefly to the irrigation of lucerne and grain, and in its various modifications is used extensively in Arizona, California, and, to a

less extent, in Idaho, Montana, and other Rocky Mountain States. It can be used best under canals which deliver water to users in large streams, since the smallest head that can be applied successfully is seldom less than two or three cubic feet per second, but heads of 5 to 10 cubic feet per second are the rule.

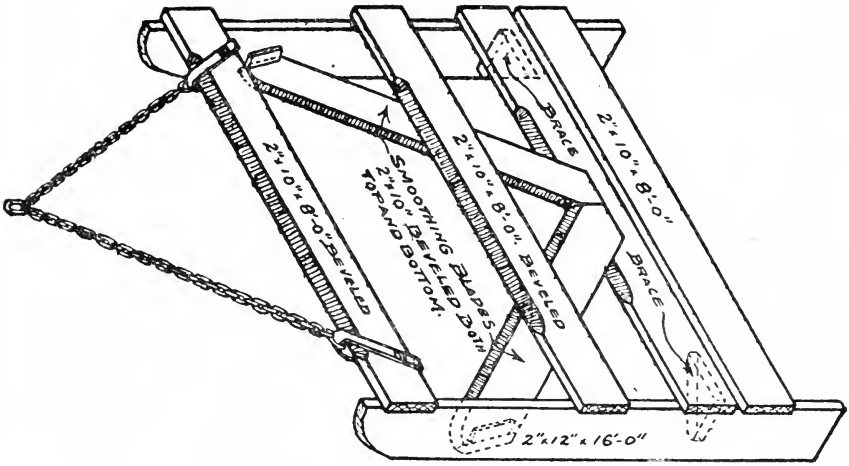


Fig. 55.—Levee smoother.

It is adapted especially to light, open soils, into which water percolates rapidly, as the use of a large stream confined between borders makes it possible to force water over the surface without great loss by percolation.

On the university farm at Davis, Cal., the borders or lands average about 50 feet wide by 900 feet long. Each levee has a base 7 feet wide and is 12 inches high, when newly made, but settles to about 10 inches before the first crop is harvested. The bed of each strip is levelled crosswise, and slopes regularly from top to bottom. In preparing the surface of this field, the barley stubble was burned, then the soil was disked and roughly graded. The location of each border was marked out either by a drag or by making a furrow. Sufficient earth to form the border was obtained by skimming the surface with scrapers. The scraper teams begin next to the head ditch and worked down. They crossed and recrossed the field at right angles to the borders, and as a scraper passed a border marking it was dumped. Each scraper width of the borders was made up of two loads, but the last load overlapped the first by half the width of the scraper. The surface of each border was then levelled to within 0.1 or 0.2 foot of accuracy. The levees when first built were rough, irregular, and steep. They were cut down to a uniform grade by a home-made device called a planer, shown in Figure 55.

In Imperial Valley, California, a 40-acre tract is divided in 22 lands, each 60 feet wide and 0.25 mile long. When the slope is too steep, the lands run diagonally across the tract. In order to lessen the first cost, the material for the borders, instead of being scraped from the high portions of the lands, is taken from the sides of the borders. This creates hollows in which water may collect, makes the mowing and raking more difficult, and frequently lessens the yield. Such borders may be made by the use of the plough and ridger (Fig. 56). In this method, a narrow strip is first ploughed, and then the ridger, drawn by a number of horses, forms the loose earth into a ridge. The cost per acre for preparing the land by the border method in this valley varies all the way from £1 to £4, depending on the character of the native vegetation and the size and number

of the hummocks. When creosote bushes and mesquite trees are surrounded by wind-driven sands, the cost may run as high as £8 per acre.

In Salt River Valley, Arizona, the customary method of preparing the land for lucerne is to remove the brush, plough the high places, and roughly level the surface with suitable scrapers. Then the borders are marked off from 30 to 50 feet apart. The spacing depends on the porosity of the soil, the configuration of the land, and the head of water available. After forming rough borders by means of four-plough furrows thrown together to form a ridge, a disk or spring-tooth harrow is run lengthwise of the lands. The borders are then crowded with a V crowder, and usually a leveller is run transversely to the borders to round them off. The land then receives a heavy irrigation, and when dry enough to work is again disked or harrowed and seeded. Such borders when first made have a base of about three feet and a height of one foot, which settles to about nine inches. The length of the borders or lands varies from ⅛ to ¼ of a mile.

The farmers on the Roswell Bench, on the south side of the Boise River, in Idaho, make the levees 66 feet apart and 300 to 1,300 feet long, depending chiefly on the topography of the land. The land is first levelled with scrapers, then ploughed and harrowed, after which the borders are marked off and thrown

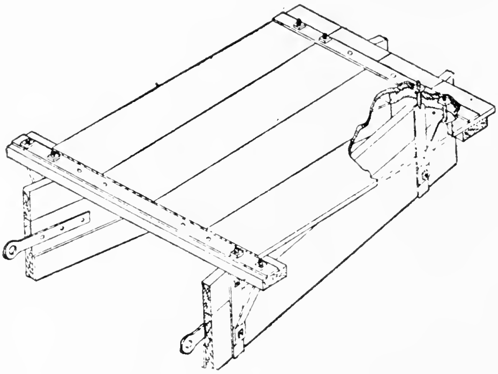


Fig. 56.—Adjustable Ridger.

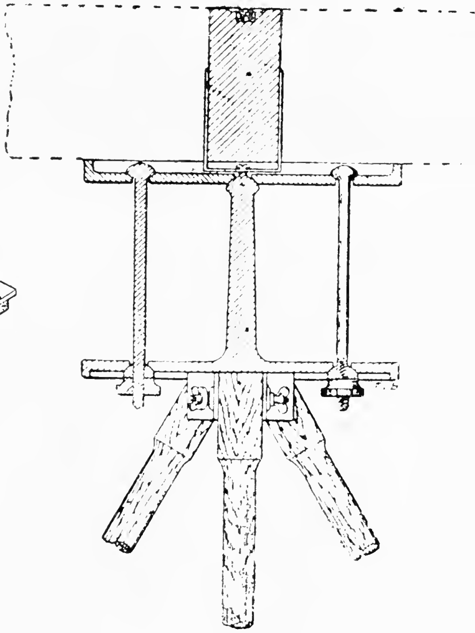


Fig. 57.—Carpenter's Spirit Level attached to a Tripod.

up by ploughing two to four furrows with a heavy plough. Before seeding, a home-made planer is dragged lengthwise and crosswise of the lands in order to fill up the hollows by cutting off the high places. The cost of preparing land in this way and seeding varies from £2 to £6 per acre, depending upon the roughness of the surface.

One of the great advantages upon this method is that it enables one man to use a large stream of water and irrigate a large area with a minimum of labour. The size of streams used in the Rillito Valley in Arizona varies. A head of about 2.5 cusecs is turned into a plat of land 30 feet wide, and takes one to three hours to reach the lower end, 660 feet distant. Two men, working twelve

hours each, with this head of water will irrigate in 24 hours 12 to 15 acres, at a cost of 10d. to 1s. per acre for each watering. In the extensive lucerne fields belonging to the Butterfield Live Stock Company, of Weiser, Idaho, the head ditch has a capacity of 3.75 to 12.5 cusecs, divided into three or four streams, and permitted to flow down as many lands until the soil is moistened to a depth of several feet. Each field receives three such waterings in a season. On the lucerne fields of Yolo County, Cal., the natural slope of the land is about 1 foot in 400. On the shorter lands the head used is seldom less than 6 cubic feet per second, but three and four times this quantity is often applied to the longer lands. On fields well laid off, with good border gates and border levees, two men can irrigate 20 to 40 acres in twelve hours, the area within these limits depending chiefly on

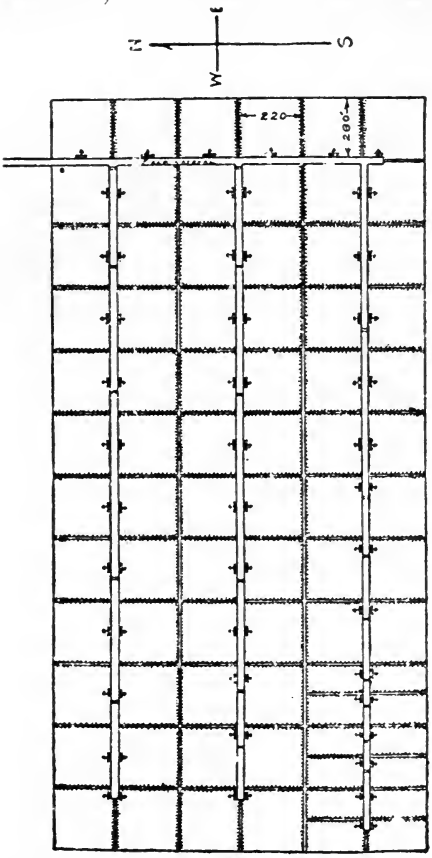


Fig. 58.—Laying out rectangular checks on farm, Modesto, Cal.

the size of the irrigating head. In Imperial Valley, California, the size of the head used varies from 1.25 to 15 cusecs. In using a head of 12.5 cusecs it is customary to divide it among five lands. With such a head it is not unusual for two men, working twelve-hour shifts, to irrigate 80 acres in 24 hours.

The Check Method.

The essential features of the check method of irrigation consist in surrounding nearly level plats of ground with low levees, and in making provision to flood each by means of a ditch and check box or gate. The enclosed spaces may be

laid out in straight lines in both directions, thus forming with their levee borders a series of rectangles, or the levees may follow more or less closely the contour lines of the natural surface of the ground, thus forming contour checks. The most favourable conditions are a light, sandy soil on a comparatively even slope of 3 to 15 feet to the mile, abundantly supplied with water. This method is also used on heavy soils, where it is necessary to hold the water on the soil to secure its percolation to the desired depth.

In California, not only does the form of the checks vary, but their size as well, some of the smaller being less than ½ acre in area, while some of the larger contain more than 10 acres.

In the Modesto and Turlock irrigation districts, the surface of the land under ditch slopes about 5 feet to the mile, and is too uneven to be irrigated without being levelled first. The unevenness consists in swales, hog-wallows, and mounds. The land is surveyed first either by an engineer or by the owner. In the latter case, use is made of a carpenter's level, with peep sights, mounted on a tripod (Fig. 57). The long side of each check should be on the flat slope, and the short side on the steep slope. A fall of 3 to 5 inches between adjacent checks is preferable to either more or less. Usually the width of checks can be so adjusted as to permit of this difference in elevation. The length of each rectangle will depend on the slope in that direction, as well as the location of the supply ditches. The field should be laid out in such a way that the levees may be built with the least handling of dirt. Rectangular checks possess many advantages over irregular contour checks, but if much of the better quality of surface soil has to be removed in order to build the former, the advantages may be more than outweighed by the damage caused by grading and the extra cost.

Fig. 58 shows in outline the rectangular checks, supply ditches, and check boxes on the farm of T. K. Beard, east of Modesto, Cal. Mr. Beard ploughs the land in the early spring to a depth of 6 inches with a four-gang plough. During

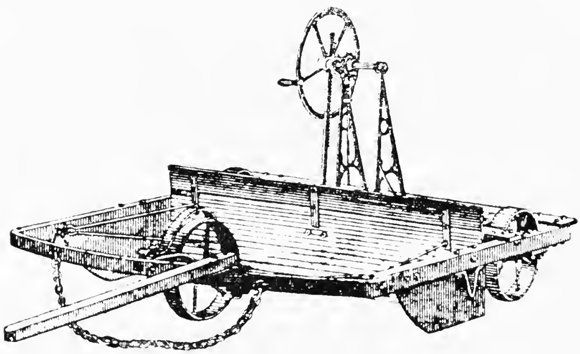


Fig. 59.—Grader.

the summer, the checks and ditches are built in a sort of rough way, no effort being made to level the floor of the checks or to smooth the levees and ditch banks. It is then heavily irrigated, and after the soil is sufficiently dry the floor of each check is carefully levelled and the levees trimmed and smoothed. For the latter purpose, the grade shown in Figure 59 is preferred. One passage of this grader across the top of each levee, and once along each side, reduces the levee to a base of 14 feet, and a height of 8 inches on the high side and 10 inches on the low side.

On the west side of the San Joaquin Valley the land to be seeded to lucerne is almost invariably formed into contour checks. A common arrangement is that shown

in Figure 60. Here the supply ditches are intended to be about 600 feet apart, and levees are built midway between. The sides of the checks conform in a measure, but not exactly, to the natural contours, having a difference in elevation of 0.3 to 0.4 foot. The average area of a check is half an acre. In 1908, prices were obtained on the cost of preparing land in contour checks and seeding to lucerne. The average cost on 2,067 acres of comparatively smooth grain land was £2 6s. per acre. Across the river in Modesto and Turlock districts, where rectangular checking is more common and where the natural surface is more uneven, the cost was estimated at £3 10s. for contour checks and £3 16s. for rectangular checks. These latter figures included ditching, but excluded the cost of seed and seeding.

In the Modesto and Turlock irrigation districts, the feed ditches are designed to carry large heads of 10 to 20 cubic feet per second. These large heads are used by the farmers in turn for short periods of time, depending upon the acreage served. In the smaller checks a head of 5 cubic feet per second will suffice, and if 20 cubic feet per second are available four checks may be irrigated simultaneously. This heading flowing on a check containing 1 acre would cover it to a depth of about 5 inches in one hour. A part of the water so applied is always lost by evaporation, but the balance percolates into the soil to furnish moisture to the plants. The skilful irrigator begins with the highest checks and works down, for the reason that all waters which escape through the gopher holes or broken levees may be then applied to dry checks. To reverse this rule might result in over-irrigating the lower checks. The average cost of irrigating for the season where proper check boxes are inserted is about 2s. 6d. an acre.

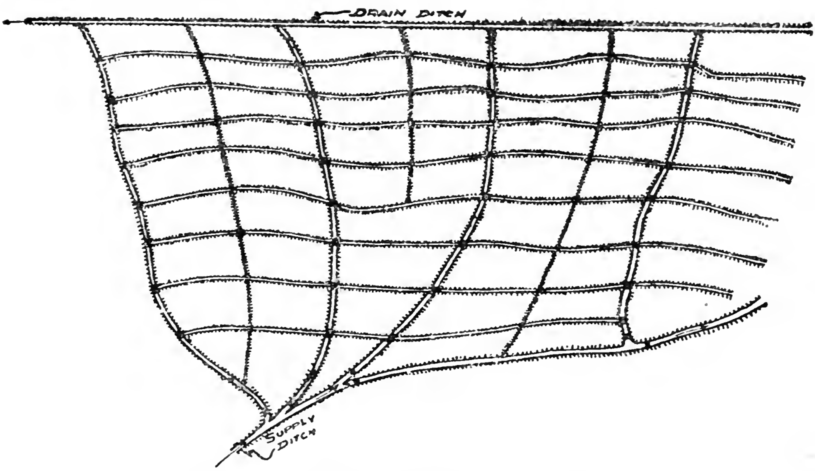


Fig. 60.—Laying out Contour Checks.

On the west side of the San Joaquin River each of the irregular compartments contains one to three acres, averaging about two acres. Few permanent wooden check boxes are used. The water is checked up by dams of coarse manure, and an opening is made in the levee bank with a shovel to admit the water. The lack of suitable boxes to control the water passing from the feed ditch into each check and the use of smaller heads greatly increase the cost of irrigating over that of the Modesto and Turlock districts. In the latter, the cost for the season was estimated at 2s. 6d. per acre, while in the former the estimate is 3s. 9d. for each watering.

The chief advantage of the check method is that one man can attend to a large volume of water, and can irrigate 7 to 15 acres in 10 hours, making the cost of applying water less than by any other method except the border method. To counterbalance this important gain, there are several disadvantages which Western farmers ought to consider. These are the removal of a considerable quantity of surface soil to form the levees, which frequently decreases the yield on the graded spots; the extra cost of preparing the land; the damage done to farm implements in crossing levees; and the fact that this method is not well adapted to a rotation of crops.

The Flooding Method.

Flooding from field ditches or laterals is still the most common method of applying water to the arid lands of Western America. In the States of Colorado, Montana, Wyoming, Utah, and to a large extent in Idaho, lucerne, clover, native meadows, and grain are irrigated in this way. This manner of wetting dry soil originated, it is believed, in the mountain States, and the past half century has witnessed a gradual evolution of this plan, so that now it has not only become firmly established, but is regarded as the best suited to the conditions under which it is practised. It can be profitably used on slopes that are too steep for other methods. Fields having a firm soil and a fall of 25 feet in 100 feet have been flooded successfully. From this extreme the slope may diminish to less than 0.1 foot in 100 feet. Its cheapness is another feature which recommends it to the farmer of limited means. Ordinary raw land can be prepared for flooding at an expense of 8s. to £1 per acre. Again, it is adapted to the use of small water supplies. In the mountain States, the irrigation systems have been planned and built to deliver water in comparatively small streams for use in flooding or in furrows, and water users should be certain that the larger volumes required for checks and borders can be secured before going to the expense of preparing their fields for either of those systems.

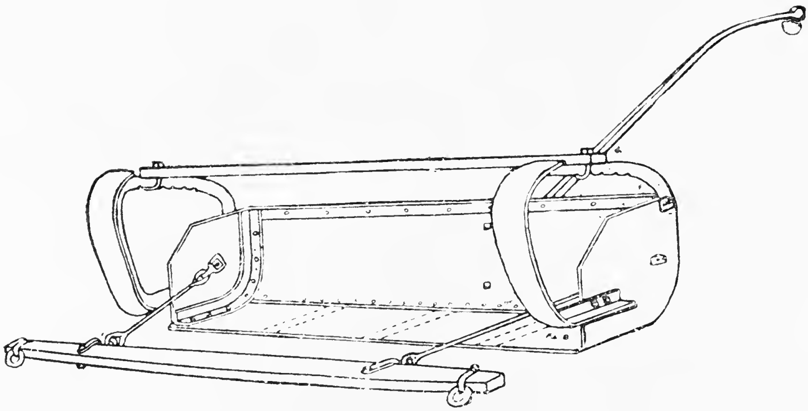


Fig. 61.—Scraper.

In grading the land for this particular method it is not customary to make many changes in the natural surface. Only the smaller knolls are removed and deposited in the low places. An effort is made always, however, to make the farm laterals fit into the natural slope and configuration of the tract to be watered, so as to bring the water to the high places. On steep slopes, the laterals may be less than 50 feet apart; on flatter slopes, they may be 200 feet or more apart. Whatever the spacing, it is always desirable to have the slope between

them as nearly uniform as possible. When the land in its natural state is uneven, the grading can be done by a grader of the kind shown in Figure 59, page 76, or a scraper of the kind shown in Figure 61. When these are used, it is often advantageous to make use of some such implement as the grader shown in Figure 62 for the final smoothing and grading. If the field in its natural state is comparatively smooth and level, a home-made drag or leveller, as shown in Figure 63, serves the purpose fairly well.

The distribution of the ditches on the field varies too widely to admit of presenting a standard plan, but Figure 64 shows an arrangement of field laterals common to the mountain States. A supply ditch, AB, is built on one side, and

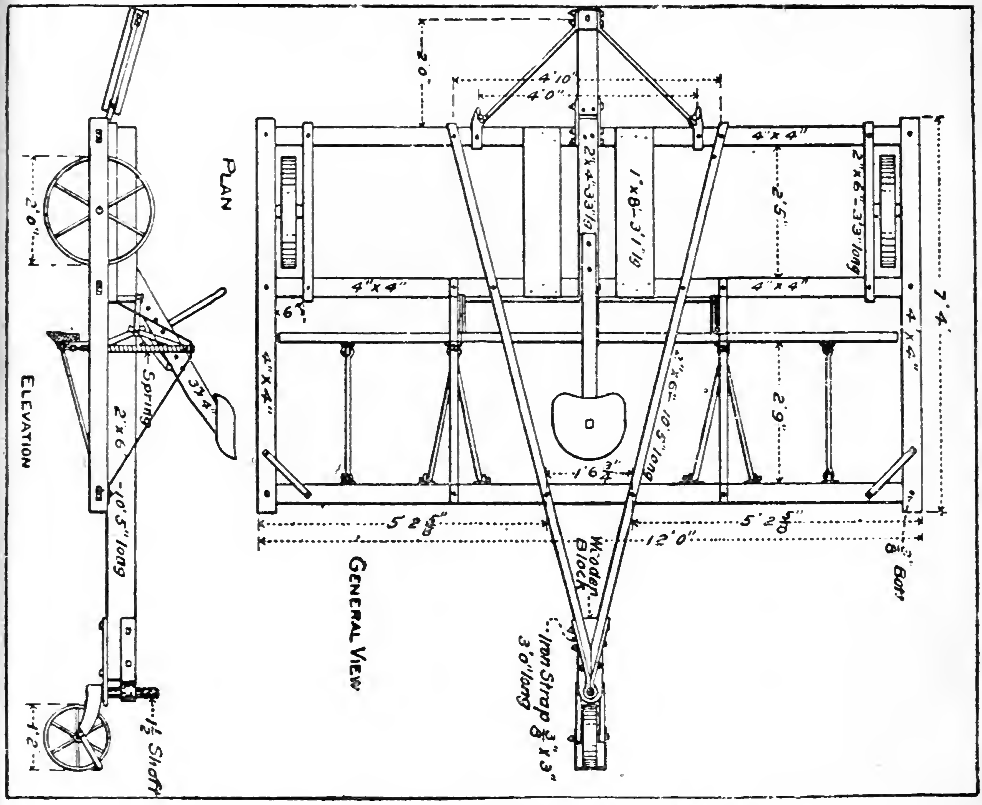


Fig. 62.—Leveller used in Gallatin Valley, Montana.

laterals, CD and EF, branch out from it on a grade of 0.5 to 0.75 inch to the rod. These laterals are spaced 75 to 100 feet apart, and are made with double mouldboard ploughs, either walking or sulky. Figures 65 and 66 illustrate other common arrangements in use in northern Colorado.

In the vicinity of Fort Collins, Colo., the main lateral is built to the highest corner of the field to be irrigated, and the smaller laterals extend out from it, spaced 75 to 225 feet apart, the spacing depending on the slope of the ground, and the coarseness of the soil. The size of the laterals is governed by the head which may be had, but on steep slopes and on soil that erodes readily, small heads are best. Around Berthoud, Colo., the land is naturally of uniform, even slope, and little grading has been necessary. Heavy timber or iron drags are used to smooth the surface after ploughing, so that the water will spread

evenly. These are built in various ways and out of whatever material happens to be available on the farm. Worn-out steel rails, such as have been removed from a railway, are often used, two rails being fastened together about 30 inches apart.

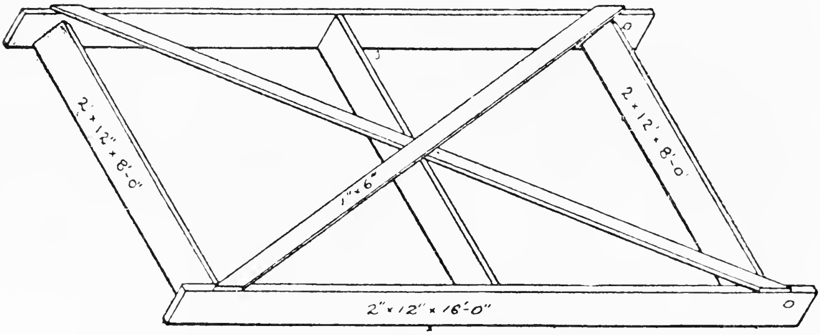


Fig. 63.—Home-made Drag or Leveller.

A team is hitched to each end and the driver rides on the drag. Once over a field with a drag of this kind is usually sufficient to make the surface quite uniform and smooth. The proper location for field laterals is usually evident to the irrigator without the use of surveying instruments, though in fields where the fall is slight it is often necessary to have a topographical survey made and the

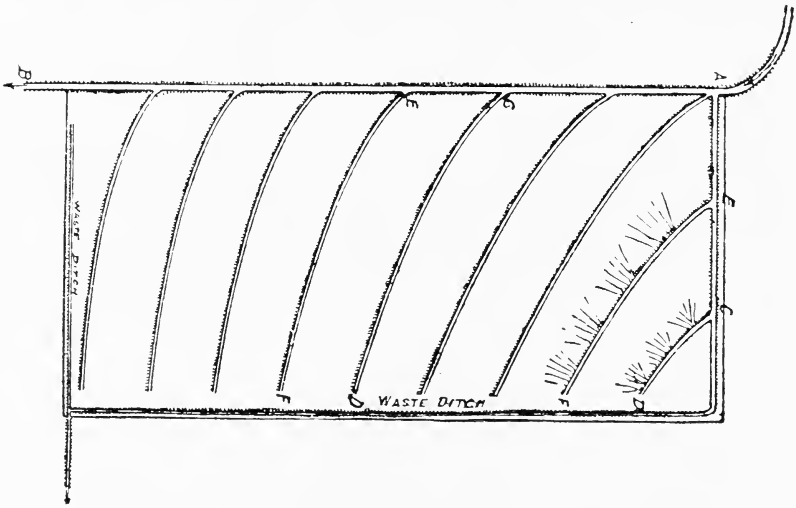


Fig. 64.—Preparing Land for Flooding in Montana.

laterals located by an engineer. Field laterals are always so located that they cover the highest parts of the field, and their distance apart in lucerne varies from 10 to 20 rods.

The head required for flooding from field laterals in northern Colorado varies from two to three cubic feet per second, and is divided between two or three laterals. Canvas or coarse manure dams are used to check the water in the laterals and to force it out over the banks and down the slopes of the fields. In less than three hours the upper foot of soil is usually thoroughly moistened. To apply one watering in this way costs from 7d. to 1s. 3d. an acre.

In flooding clover and lucerne fields in Montana the field ditches usually run acros the field on a grade of 0.5 to 0.75 to the rod. (See Fig. 64.) The spacing between ditches varies with the slopes, the smoothness of the surface, and the volume of water, but 80 feet is about an average. The head used is seldom less than 1.5 or more than 4 cubic feet per second, the larger heads being divided between two or three ditches. In irrigating, a canvas dam is first inserted in each ditch or set of ditches, 75 to 100 feet below the head. The water is then turned into each channel, and flows as far as the canvas dam, by which it is checked, and, as a consequence, rises and flows over the lower places of the lower bank or through openings made with the shovel. When these small tracts have been watered, the canvas dam is raised, dragged down the lateral 75 to 100 feet, and

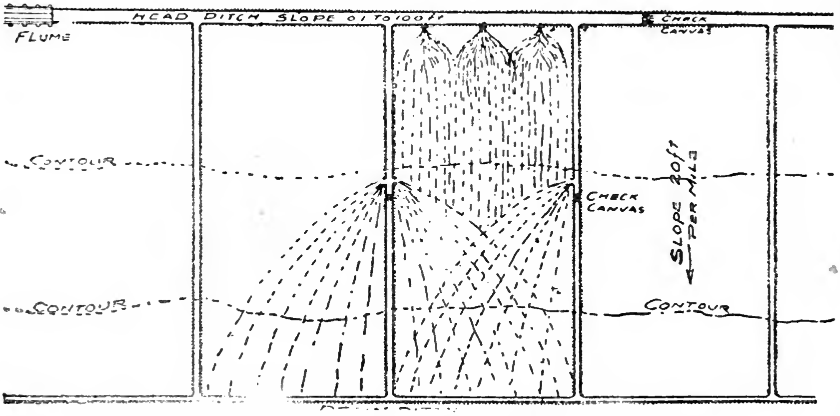


Fig. 65.—Flooding from head ditches in Northern Colorado.

again inserted in the channel to serve the next tract. Manure dams sometimes take the place of the movable canvas dams. Some time before a field is to be irrigated, and after the ditching is done, coarse manure is placed in small heaps within each ditch channel at suitable intervals, and each heap is covered with earth on its upper face to a depth of one to two inches. When this check has served its purpose, it is broken, and the water flows down until stopped by the next check. In some instances, permanent wooden check boxes are inserted in each lateral, while in others the canvas dam is used. The thorough irrigation of four acres is considered a good twelve hours' work for one man. By the use of 2.25 cusecs, two men can irrigate seven to 10 acres in 24 hours at a cost of 1s. 10d. to 2s. 9d. per acre.

In the Salt Lake Basin, the heads of water used by the irrigators of lucerne vary considerably with the flow of the streams. In spring, heads of 4 to 6 cubic feet per second are common, while later in the season when the streams are low, they are reduced to 1 to 3 cubic feet per second. A field is usually divided into strips 200 to 500 feet wide by laterals extending across it (Fig. 64). A permanent wooden check box or a canvas dam is inserted in the main supply ditch below each cross ditch, causing the water to flow into the cross ditch. From there it is spread over the surface through small openings in the ditch bank, and any excess water is caught up by the next lower ditch. In this way each ditch serves a double purpose, acting as a drainage channel for the land above it, and as a supply channel for the land below it.

In summarising the advantages of the flooding method, it may be said that in first cost it is one of the cheapest, it is adapted to the delivery of small volumes of water (1.25 to 2.5 cusecs) in continuous streams, it is particularly well adapted to forage and cereal crops of all kinds, the top soil is not removed from the high

places to fill up the low places, and firm soil, although it be on steep and irregular hillsides, can be successfully watered.

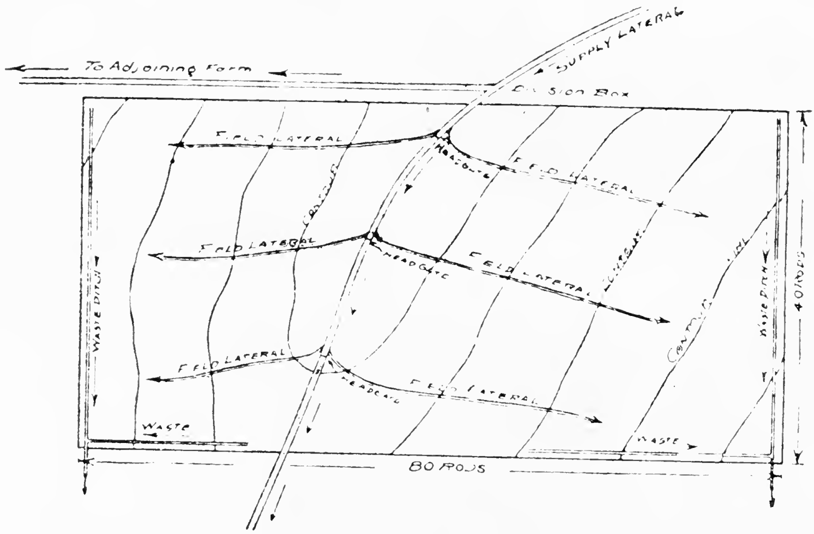


Fig. 66.—A 20-acre Lucerne Field near Berthoud, Colo., showing supply lateral, field laterals, contours, and waste ditches.

The chief disadvantages consist in the fatiguing labour required to handle the water, the small area which one man can irrigate in a day, the difficulty in applying water after dark, and the unequal distribution of water on the field unless more than the average care is exercised.

The Furrow Method.

Lucerne, native meadows, and grain are most commonly irrigated by one of the methods previously described rather than by the furrow method, which is the usual method of irrigating orchards, gardens, root crops, and vegetables. The irrigating of lucerne from furrows is at present confined to the Yakima Valley, Washington, to portions of the Snake River Valley in southern Idaho, and to comparatively small areas in other States. In the localities named the soil is a fine clay loam which runs together, puddles when wet, and bakes and cracks when dry. Flooding the surface by any of the customary methods tends to puddle the top layer of soil, which becomes quite hard when the moisture is evaporated.

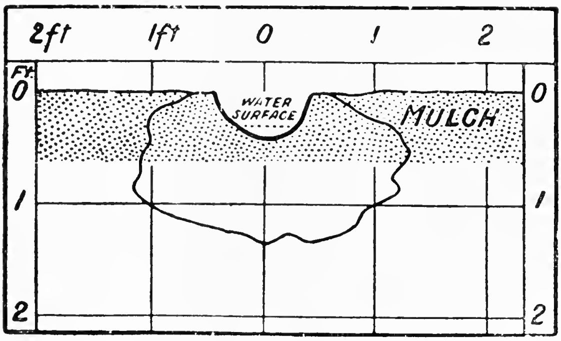


Fig. 67.—Outlines of percolation from furrow 5 inches deep, in 7 hours.

The puddling and baking processes injure lucerne, and it was with the object of keeping as much as possible of the surface dry that furrows were introduced. When a small stream is permitted to run in the bottom of a furrow for several hours, the soil beneath and for some distance on each side becomes wet, while the surface may remain nearly dry. This is shown in Figure 67, which gives the area wetted from a furrow five inches deep in seven hours, as determined in one of the orange orchards of southern California.

The lucerne grown in the Yakima Valley in Washington is practically all irrigated by means of furrows. The grading is usually done by buck-scrapers (Fig. 68), while a long, rectangular drag similar to the one shown in Fig. 63 (page 80) removes most of the surface inequalities that remain after the surface

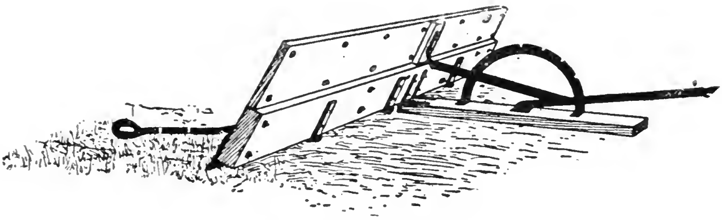


Fig. 68.—Buck Scraper.

has been levelled roughly by the scraper. The float is made of two 2 by 6 inch timbers about 20 feet long, held in position by crosspieces of the same size 6 feet long.

The common practice is to run the furrows across the entire width or length of a field, and in consequence their length varies from 20 rods or less in small fields to 80 rods in large fields. As a rule, the furrows are too long. Farmers object to cutting up a field by head ditches, but in a climate like that of the Yakima Valley in midsummer by far the most essential element in plant production is water, and all other considerations should give place to it. It has been shown that water is rarely distributed evenly in furrow irrigation and that much is lost by deep percolation. To increase the length of a furrow beyond 660 feet, or one-eighth of a mile, not only increases the loss, but renders a uniform distribution more difficult to secure. Except in rare cases, this distance should be regarded as the limit for the length of furrows. In light, sandy soils, having a porous gravel stratum beneath, the length may well be reduced to 250 feet.

Figure 69 shows the manner of dividing a lucerne field for furrow irrigation at Kennewick, Wash. Lumber head flumes, either 8 by 8 inches or 6 by 6 inches, are placed along the upper boundary of each strip and the direction of the flow in both flumes and furrows is indicated by arrows. Auger holes are bored through one side of the flume flush with the bottom at points where water is to be delivered to the heads of furrows. A short piece of lath revolving on a nail controls the flow from each opening. On steep grades a cleat on the bottom of the inside of the flume nailed on crosswise just below each opening will dam back the water and increase the discharge.

When flumes are considered too costly, the water is distributed among the furrows through wooden spouts set in the bank of an ordinary earthern ditch (Fig. 70). These head ditches when in operation are divided into a series of level spaces by means of drop boxes which hold the surface of the water at the desired elevation. The spacing of these drop boxes depends on the grade of the head ditch, and

their cost averages about 10s. each. Spouts are made usually by nailing together four laths. There is a special lath on the market somewhat heavier than the

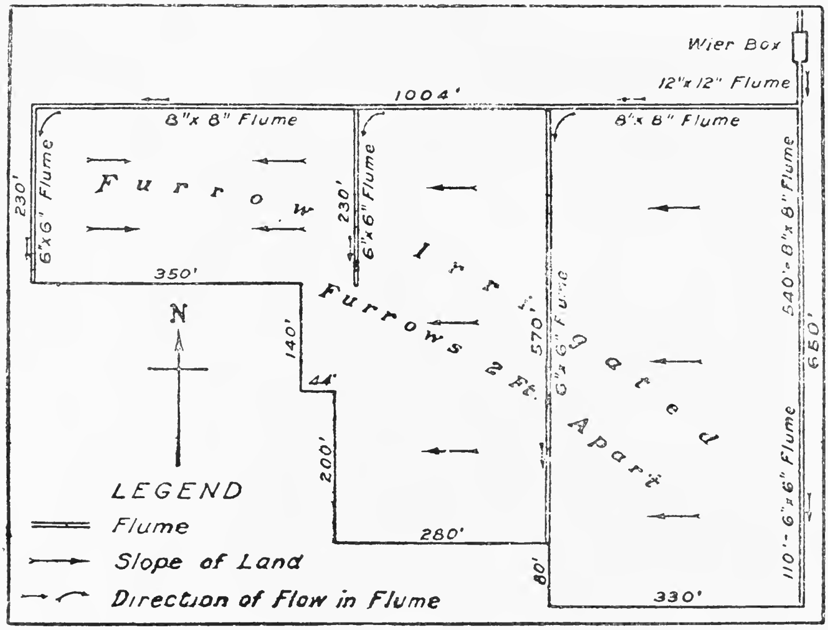


Fig. 69.—Showing tract prepared for furrow irrigation.

ordinary one used for plastering buildings, being 0.5 inch thick, two inches wide, and three feet long. Four of these when nailed together cost about 1¾d.,* and each spout in place costs about 3d. Assuming that they are spaced four feet apart, the spouts for a square tract of 10 acres would cost £2 3s., or slightly more than 4s. per acre. The cost of an ordinary head ditch, with four drops or check boxes, would be about £3 for the same tract, or 10s. per acre for both, exclusive

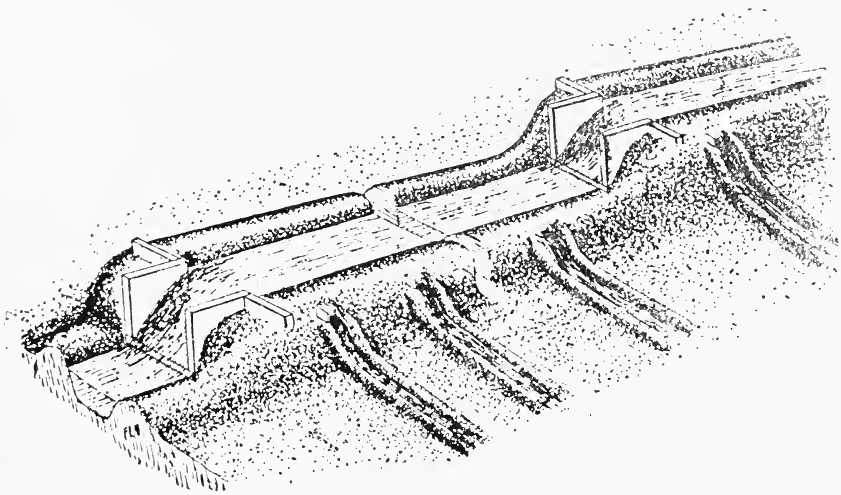


Fig. 70.—Manner of placing tubes in ditch bank for furrow irrigation.

*Sawn hardwood of same dimensions would be suitable—cost about the same.

of grading, smoothing, and levelling. Tin tubes, 0.5 inch in diameter, one to each furrow, have sometimes been used instead of the wooden tubes. When set 0.5 inch below the water surface, each tube discharges about .002 cusec, which is about right for a slope of three per cent. The length of the tin tubes is governed by the size of the ditch bank. The tubes are set while the water is in the ditch, and are kept at the same level between check boxes. The cost of tin tubes two feet long is about 12s. per hundred. In many places neither flumes nor tubes are used. Water is taken through cuts in the ditch bank and divided among

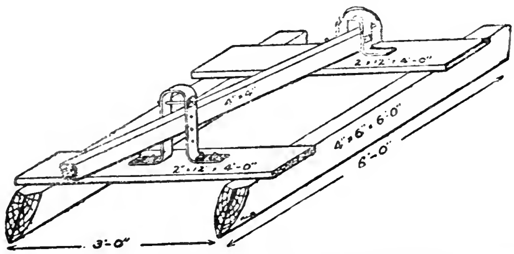


Fig. 71.—Furrower used on experimental farm, Wyo.

the furrows as evenly as possible by directing it with the shovel. This practice reduces the cost of preparing the land for irrigation, but it increases the cost of applying water, and does not secure an even distribution among the furrows.

Furrows in lucerne fields are most commonly made by the use of a marker, or furrowing sled (Fig. 71). Sleds with more than two runners are sometimes used, reducing the time required for furrowing, but not producing quite so satisfactory furrows, since an obstruction under one of the outside runners will lift all but the other outside runner out of the ground and leave obstructions in the

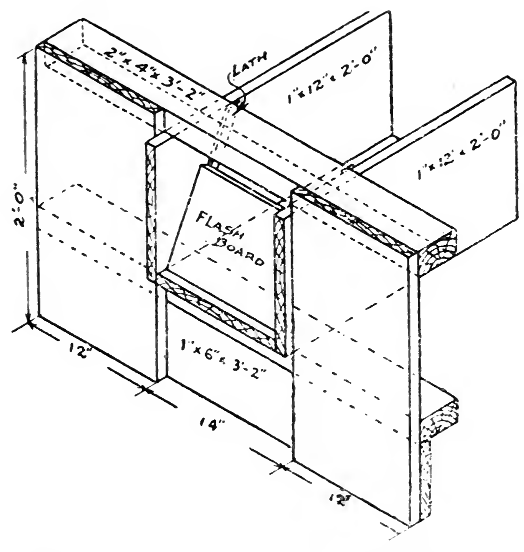


Fig. 72.—Check box for furrow irrigation.

furrows, which, if not removed, will cause the flooding of the surface. Sometimes a marker is put on the sled to indicate the place for the next furrow.

For the irrigation of most of the crops grown in the vicinity of Twin Falls, Idaho, the feed ditches are laid out across the field as nearly parallel as possible on a grade of 2 to 6 inches to 100 feet and 300 to 500 feet apart. Furrows are made in the direction of the greatest slope and approximately at right angles to the feed ditches. Starting at the upper end, a wooden check is inserted in the ditch at the end of each fall of 12 inches. Thus, if the ditch has a fall of 4 inches to 100 feet, the checks are placed 300 feet apart. Each check box is provided with a removable flashboard, which, when in place, backs the water to the next check above, and at the same time permits the surplus water to flow over its top to supply the checks below (Fig. 72). Lath tubes 16 to 24 inches long are inserted in the lower ditch bank about 3 inches below the water level formed by the flashboards when in place. These tubes are put in while the check is full of water in order that all of each set may be on the same level and that water may be had for puddling. The flow from each tube may be divided among several furrows. Ordinarily a 40-acre farm will require about 30 check boxes and 1,800 tubes. Nearly one-half the tubes ought to be 24 inches long to insert near the check boxes where the bank is heaviest, while the remainder may be 16 inches long. The check box shown in the sketch (Fig. 72) calls for 17 super. feet of lumber, but a serviceable box can be made out of old packing boxes.

Some of the advantages of this method over ordinary furrow irrigation are :—A constant head over the inlets of each set of tubes while the surplus passes down the field ditch; the opportunity to use one or all or any combination of checks at the same time, as it is possible to regulate the head, and consequently the discharge, by raising or lowering the flashboard; and the automatic character of the water distribution while irrigating.

No fixed rule can be given as to the proper spacing of the furrows or the time water should run in each. In heavy retentive soils, the furrows may be 2

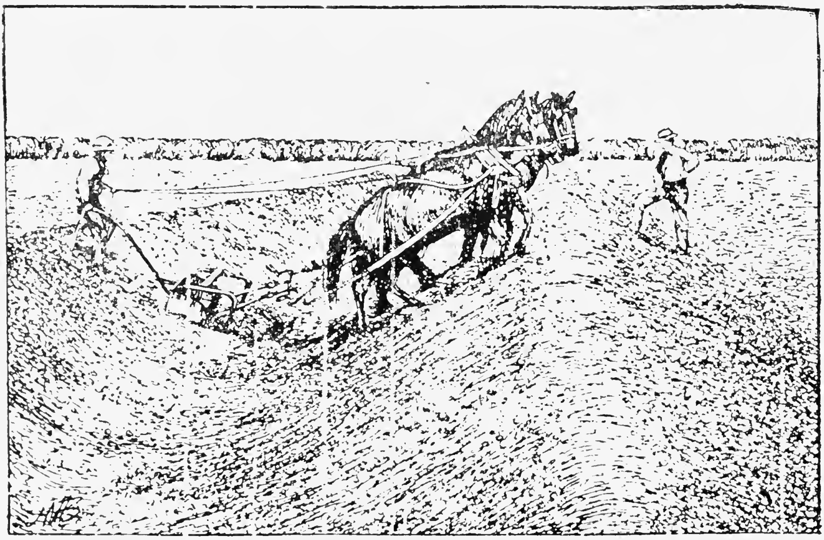


Fig. 73.—Building a supply ditch.

to 2.5 inches deep and only 16 inches apart, while in more open soils the furrows may 48 inches apart.

The amount of water which should flow in each furrow depends on the character of the soil and the slope. It is a common practice in the Yakima Valley

to space the furrows 18 to 24 inches apart when the seeding is done, but as the plants grow their roots soon penetrate several feet into the soil, and alternate furrows are then abandoned. If the tract contains 10, 20, or 30 acres the furrows run all the way across, if the slope will allow it. Water is frequently run a quarter of a mile in the small furrows. In furrows 660 to 1,320 feet long in sandy loam, the water has to be kept running continuously for about two days, and consequently there is usually much waste due to deep percolation. In distributing water in furrows it is a good plan to follow the practice of the irrigators of the orange belt in southern California, who turn into each furrow, until the furrows are wet, three or four times as much water as will be permitted to remain, and then reduce the flow.

Farm Ditches.

The capacity and, to some extent, the location of farm ditches depend chiefly on the method of applying water. In the border method the supply ditch is usually large and so located as to convey a sufficient volume of water to the head of each land. In Imperial Valley, in California, these head ditches, as they are called, have a bottom width of 6 feet and a surface width of 12 to 14 feet.

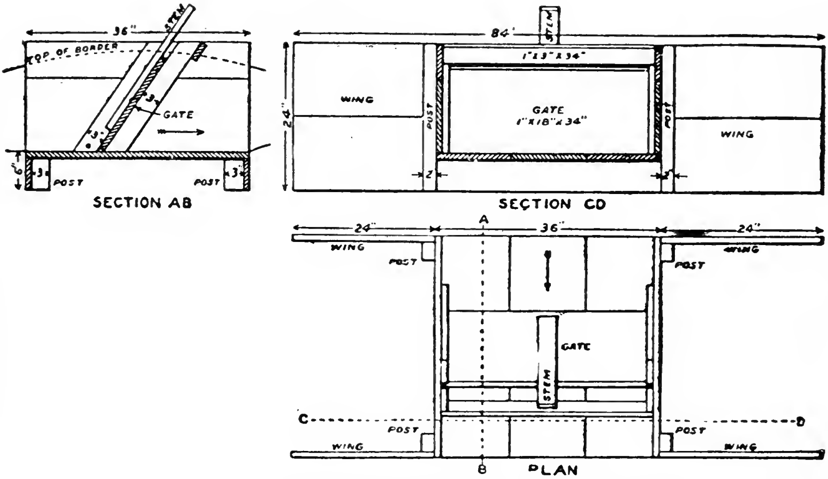


Fig. 74.—A border gate used in Imperial Valley.

In building a ditch of this size, a strip 6 feet wide on the centre line of the ditch is ploughed 6 inches deep. Then parallel strips, also 6 feet wide, are ploughed 8 feet distant from it. Scraper teams then cross and recross these, taking dirt from the ploughed strips and dumping it on the unploughed spaces to form the banks (Fig. 73). The banks when completed are about 2 feet above the natural surface of the ground, and the bottom of the ditch is 6 to 10 inches below it. When it is deemed best not to create a depression at the outer toe of each embankment, the borrowed dirt is taken from the high parts of the adjacent land.

The water required for each land is withdrawn from the head ditch through a border gate. These are usually made of wood. Figure 74 shows the type of border gate used by F. N. Chaplin, of Holtville, in Imperial Valley. It requires 49 super. feet of redwood, which, at £8 8s. per thousand, makes the lumber cost

8s. 3d. The hardware, carpentry, and setting increase the cost to about 13s. If it is assumed that 22 gates are needed for a 40-acre tract, the cost per acre for the

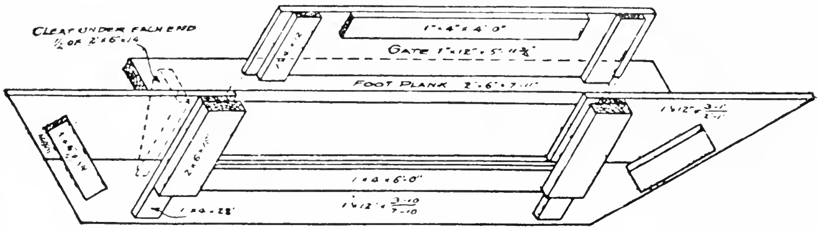


Fig. 75.—Border gate used near Sunset City, Cal.

border gates is 7s. 2d. A cheaper border gate is shown in Figure 75, which represents the kind used on a lucerne tract at Sunset City, Cal. In some localities concrete is being substituted for wood, and Figure 76 shows a border gate of this material, quite generally used for the irrigation of lucerne in Yolo County, Cal.

In the check method of irrigation, the volumes used do not differ materially from those required to flood the lands in the border method, and the feed ditch

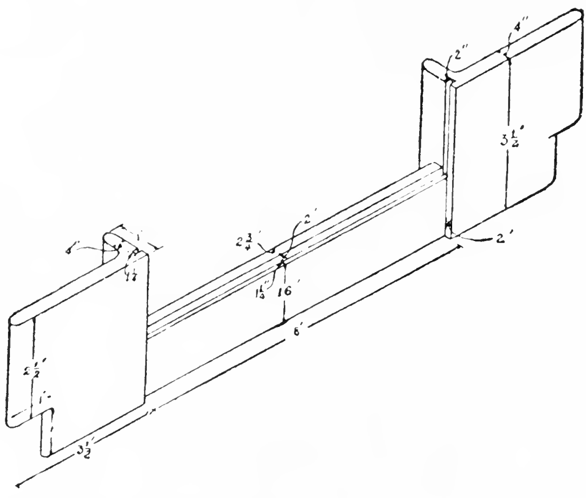


Fig. 76.—Concrete gate used in Yolo County, Cal.

for the checks corresponds in size and capacity to that of the head ditch for borders. Cross sections of common forms of supply ditches are shown in Figures

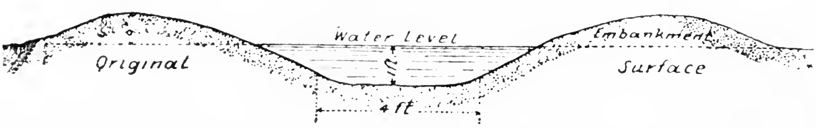


Fig. 77.—Supply ditch with bottom width of 4 feet.

77 and 78. The carrying capacities of these ditches under different grades are given in the accompanying table :—

MEAN VELOCITY AND DISCHARGE OF DITCHES WITH DIFFERENT GRADES.

Supply Ditch, Figure 77.

Grade.			Mean velocity in feet per second.	Discharge.
Inches per rod.	Feet per 100 feet.	Feet per mile.		Cubic feet per second.
$\frac{1}{16}$	0·03	1·58	0·84	4·20
$\frac{1}{8}$	·06	3·33	1·08	5·40
$\frac{1}{4}$	·13	6·67	1·54	7·70
$\frac{3}{8}$	·19	10·00	1·89	9·50
$\frac{1}{2}$	·25	13·33	2·20	11·00
$\frac{5}{8}$	·31	16·67	2·45	12·20
$\frac{3}{4}$	·38	20·00	2·69	13·40

Supply Ditch, Figure 78.

$\frac{1}{16}$	0·03	1·67	1·03	11·60
$\frac{1}{8}$	·06	3·33	1·48	16·70
$\frac{3}{16}$	·09	5·00	1·82	20·50
$\frac{1}{4}$	·13	6·67	2·11	23·70
$\frac{5}{16}$	·16	8·33	2·35	26·40
$\frac{3}{8}$	·19	10·00	2·58	28·00
$\frac{7}{16}$	·22	11·67	2·80	30·50

In flooding land from field laterals, two kinds of channels are needed. The larger ones convey the water to the highest corners of the fields and along one or two borders of each field ; the smaller distribute the water over the field. In this method of applying water, smaller streams are used than in either

Fig. 78.—Supply ditch with bottom width of 6 feet.

the check or border method. Except on large farms, the stream seldom exceeds 3 cubic feet per second, and is usually between 2 and 3 cubic feet. On ordinary grades, only a small channel is needed for this volume. Such channels are made by ploughing first a strip as wide as the surface of the ditch is to be when full and removing the loose dirt by one of several designs of A

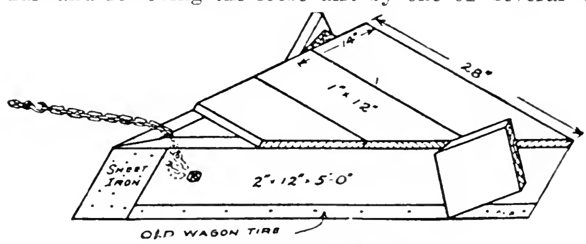


Fig. 79.—"A" Crowder.

crowders, two of which are shown in Figures 79 and 80. One of the best implements for making field laterals is a 14 or 16 inch lister plough on a sulky frame. Figures 81 and 82 show cross sections of laterial ditches made in this way, while Figure 83 represents a common type of supply ditch. The effect which grade has upon such channels is shown in the accompanying table, giving discharges of these ditches, with various grades.

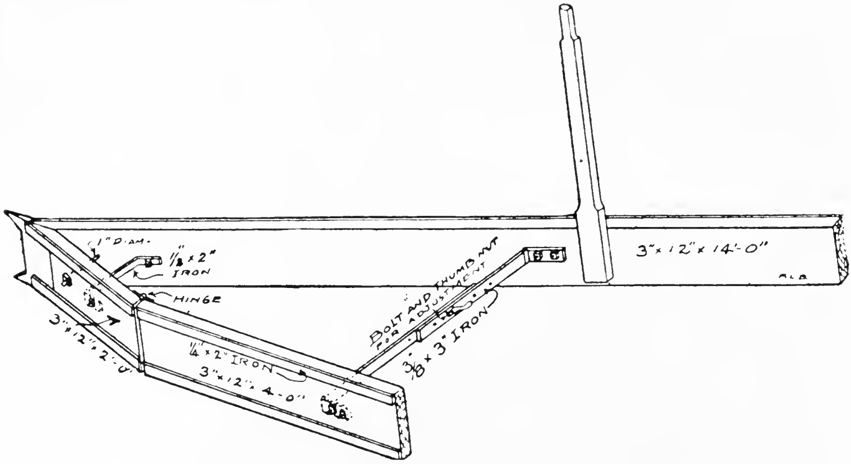


Fig. 80.—Adjustable "A" Scraper or Crowder.

Fig. 81.—Lateral Ditch with bottom width of 14 inches.

Fig. 82.—Lateral Ditch with bottom width of 16 inches.

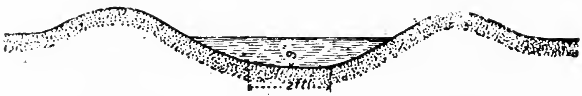


Fig. 83.—Lateral ditch with bottom width of 2 feet.

TABLE GIVING THE MEAN VELOCITY AND DISCHARGE OF DITCHES WITH DIFFERENT GRADES.

Lateral Ditch, Figure 81.

Grade.			Mean velocity in feet per second.	Discharge.
Inches per rod.	Feet per 100 feet.	Feet per mile.		Cubic feet per second.
$\frac{1}{2}$	0·25	13·33	1·01	0·67
$\frac{3}{4}$	·38	20·00	1·23	·81
1	·51	26·67	1·42	·93
$1\frac{1}{4}$	·63	33·33	1·59	1·05
$1\frac{1}{2}$	·76	40·00	1·75	1·16
2	1·01	53·33	2·04	1·35
$2\frac{1}{2}$	1·26	66·67	2·28	1·50
3	1·51	80·00	2·50	1·64
$3\frac{1}{2}$	1·77	93·33	2·70	1·78

Lateral Ditch, Figure 82.

$\frac{1}{4}$	0·13	6·67	0·82	0·80
$\frac{1}{2}$	·25	13·33	1·16	1·00
$\frac{3}{4}$	·38	20·00	1·42	1·30
1	·51	26·67	1·64	1·50
$1\frac{1}{4}$	·63	33·33	1·84	1·70
$1\frac{1}{2}$	·76	40·00	2·02	1·80
$1\frac{3}{4}$	·88	46·67	2·18	2·00
2	1·01	53·33	2·34	2·10
$2\frac{1}{2}$	1·26	66·67	2·61	2·40

Lateral Ditch, Figure 83.

$\frac{1}{8}$	0·06	3·33	0·79	2·08
$\frac{1}{4}$	·13	6·67	1·13	3·00
$\frac{1}{2}$	·25	13·33	1·60	4·20
$\frac{3}{4}$	·38	20·00	1·97	5·20
1	·51	26·67	2·28	6·00
$1\frac{1}{4}$	·63	33·33	2·57	6·80

THE SUB-IRRIGATION OF LUCERNE FIELDS.

As a general thing, lucerne is irrigated from the surface downward by one of the methods previously described. There is, however, a small percentage of lucerne lands, probably not more than 5 per cent. of the total, which is irrigated from below. Frequently the seepage water from porous, earthen ditches and the waste water from irrigated areas pass through the subsoil of lower fields sufficiently near the surface to sub-irrigate them. In other places, these seepage waters collect at the lower levels and raise the ground water near enough the surface to supply the plants with the needed moisture. It is questionable if lucerne growers should place much dependence on this mode of supplying moisture to the plant. What is gained in not having to irrigate is usually more than lost in damage done to both soil and crop by the rise of the ground water. Wherever alkali is prevalent the rise of the ground water near the surface is almost certain to be followed by an accumulation of alkali on the surface. Again, the fact that lucerne fields sub-irrigate is usually nature's way of giving warning that the ground water is rising dangerously near the surface, and observations should be made to determine if the level is above the danger limit. One of the best ways of making such determinations is by means of bored test wells. These are made by boring holes from two to four inches in diameter in different parts of the field and noting at regular intervals the elevation of the ground water in each. Where the subsoil is a clay or a clay loam, no lining will be necessary other than a joint of drain tile or a short wooden tube. Where the sub-soil is loose, it may be necessary to line the wells with thin galvanised iron or with a wooden box. The wells may be connected by a line of levels, the elevations being taken on the tops of stakes driven beside the wells. These well records, if taken at weekly or even monthly intervals, for several years, will show at a glance not only the position of the ground water, but also its rise and fall throughout the seasons. Whenever it is found that the water table stands for any considerable time at less than four feet from the surface there is cause for alarm, and measures should be taken to prevent such an accumulation of seepage waters or to remove the surplus by drainage.

Lucerne is sub-irrigated also from the beds of streams. On bottoms the danger is not so great, because there is less alkali present and the height of the ground water is governed by the condition of the stream. It happens often that when the water table is at its highest point the lucerne plants are dormant or nearly so, and as a result are not so readily injured. Two cases of successful sub-irrigation from stream channels are here cited by way of illustration.

On the farm of J. A. King, located on the second bottoms about five miles north-east of Boulder, Colo., the water table is 10 to 12 feet below the surface. An average yield of lucerne of four tons per acre has been obtained for the past nine consecutive seasons from this farm without any perceptible deterioration. The crop was irrigated the first year, but after that the roots had evidently reached water and continued to draw their supply from that source.

On the Arkansas River south of Cimarron, Kans., John Bull has a lucerne field of over 50 acres which is sub-irrigated. The water table is found at a depth of 6 to 8 feet, and the yield is usually one ton at each cutting. It is cut three to five times each season, and in some years one crop of seed and two crops of hay are raised.

Throughout the arid region there are a few localities where sub-irrigation is quite generally practised. Perhaps the most notable of these is to be found in the vicinity of the towns of St. Anthony and Sugar City, in the Upper Snake

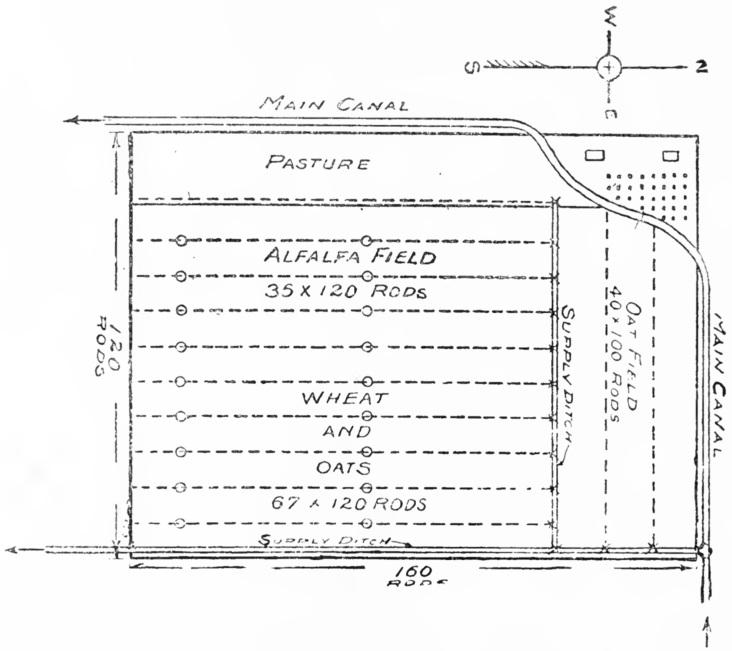


Fig. 84.—One hundred and twenty acre sub-irrigated farm of Idaho.

River Valley in Idaho. This sub-irrigated district comprises an area of about 60,000 acres. A characteristic of the subsoil of this large area is that it is composed of sand and gravel, sometimes mixed with cobble rock to the lava bedrock, which is found at depths varying from a few feet to 90 feet. The surface soil around St. Anthony is a dark-coloured gravelly loam 2 to 4 feet deep.

On the Egin Bench it is a dark sandy loam 1.5 to 5 feet deep, while around Sugar City it is a clay loam 4 to 6 feet deep. The land slopes to the south and west at the rate of about 10 feet to the mile.

At first ordinary ditches were built, and for years attempts were made to irrigate the land by the usual methods. These failed, however, since all the water turned into the ditches soon sank into the porous subsoil beneath. In time much of the subsoil filled up with water, due to an impervious lava bedrock, and the top layers of soil became moistened from below. This condition led to the farmers to adopt a new method of irrigation, a type of which is shown in Figure 84. On a farm of 120 acres, the property of C. H. DeCamp, located 12 miles south of St. Anthony, Idaho, the main canal passes along the north and west boundaries. From this a supply ditch is run which feeds the smaller laterals. These laterals are shallow ditches about 3 feet wide and 6 inches deep, and divide the farm into strips. On the majority of farms the laterals do not exceed 1,320 feet in length, and are spaced 100 to 300 feet apart. On this particular farm their length is increased beyond the average, and their width decreased. In this mode of irrigation, no water is spread over the surface; the laterals merely distribute .37 to .50 cusec each to different parts of the field, where it soon joins the ground water by sinking through the bottoms of the shallow ditches. The land is planted in the early spring when the ground water is low, and then water is turned into the ditches and kept in day and night until the ground water rises sufficiently near the surface to supply the needed moisture to the roots of plants. Thereafter the height of the ground water is regulated by the amount of water turned into the supply ditch. The rise and fall of the ground water is determined by means of small boxes set in the ground three to five feet deep, as indicated by the circles in Fig. 84. Twenty to thirty boxes are usually required for each 80-acre farm. All water is turned out of the main canal prior to 15th September to permit the land to dry out for the harvesting of such crops as sugar beets, potatoes, etc. When the crops are removed, a small stream is left running in the main canal all winter; but notwithstanding this supply, the ground water usually falls from 6 to 20 feet below the surface during the fall and winter months. This somewhat novel method of applying water has led to the adoption of a rotation of crops which seems to suit both water and soil conditions. Lucerne does not do well after the third year. This is chiefly due to the height at which the ground water is kept during the spring and summer months. Then, too, the soil is lacking in humus. These conditions have led the farmers to grow lucerne on a tract for two or three years, and then to turn the lucerne under and raise grain, sugar beets, and potatoes for the next three years. Under this rotation the yields per acre on well-managed farms are 40 to 60 bushels of wheat, 75 to 110 bushels of oats, 50 to 90 bushels of barley, 300 to 500 bushels of potatoes, 15 to 20 tons of beets, and 4 to 6 tons of lucerne. The land sells for £20 to £30 an acre.

Amount of Water Required.

Lucerne requires more water than most crops. This is readily accounted for by the character of the plant, the rapidity with which it grows, the number of crops produced in one season, and the heavy tonnage obtained.

As a result of careless practice there is a lack of uniformity in the quantity of water used, the volumes applied frequently being far in excess of the needs of the crop. The majority of the records collected and published by this Office shows a yearly duty of water for lucerne ranging from 2.5 to 4.5 feet in depth over the surface, while in quite a large number of cases the volumes applied would have covered the area irrigated to depths of six to 15 feet.

From the large number of measurements made on the duty of water, it is possible to select some that possess great value, since they indicate what can be accomplished with a given quantity of water.

During the season of 1904 careful measurements were made by C. E. Tait, of this Office, of the amount of water used on lucerne fields in the vicinity of Pomona, Cal. The rainfall at Pomona for the winter of 1903-4 was much below the normal, and amounted to about 9.1 inches. The quantity of irrigation water applied by pumping averaged 2.3 feet in depth, and the yield of cured hay averaged from 1 to 1.5 tons per acre per crop, five or six crops being common. These figures are corroborated by many others collected in southern California. Perhaps in no other locality of the arid region is a greater tonnage of lucerne obtained, yet in a climate of scanty rainfall, having a long, dry, hot summer, only a comparatively small amount of water is used. About a third of the 9,000 acres irrigated by the Riverside Water Company is in lucerne, and for the past seven years the average depth applied has been 2.31 feet, while the depth of rainfall and irrigation water combined has averaged 3.18 feet.

In 1903 the writer, when Director of the Montana Experiment Station, applied different depths of water to seven plats of lucerne, with the results given in the following table. It will be seen that a high tonnage for so short a season as prevails in Montana was obtained from plat 5 with the use of two feet of water. By irrigating plat 6 seven times, and plat 7 eight times, it was possible to increase the yield to the amounts stated. The results of this experiment seem to confirm the best practice of southern California, which may be summed up by stating that in localities having an annual rainfall of about 12 inches remarkbly heavy yields of lucerne may be obtained from the use of 24 to 30 inches of irrigation water, providing it is properly applied.

QUANTITIES OF WATER APPLIED TO LUCERNE AND YIELDS SECURED, MONTANA EXPERIMENT STATION.

Plat number.	Depth of irrigation.	Depth of rainfall.	Total depth.	Yield per acre of cured lucerne.
	Feet.	Feet.	Feet.	Tons.
1	0·5	0·70	1·20	4·61
2	None	·70	·70	1·95
3	1·0	·70	1·70	4·42
4	1·5	·70	2·20	3·75
5	2·0	·70	2·70	6·35
6	2·5	·70	3·20	7·20
7	3·0	·70	3·70	7·68

The Proper Time to Irrigate Lucerne.

The general appearance, and more particularly the colour of the plant, are the best guides, perhaps, as to when water is needed. When healthy and vigorous lucerne is of a light-green colour; but when the supply of moisture is insufficient the leaves take on a darker and duller shade of green and begin to droop, and unless water is provided both stems and leaves wither and die. Another test is to remove a handful of soil 6 inches or so beneath the surface and compress it in the hand. If it retains its ball-like shape after the pressure has been removed, and shows the imprints of the fingers, the soil is sufficiently moist, but if it falls apart readily, it is too dry. In connection with such tests it is well to bear in mind that they are more or less influenced by both soil and climate. It is therefore necessary to observe the growth of the plant closely on all new lucerne fields

to determine if possible how far such tests may be relied upon, the chief object being to maintain at all times as nearly as practicable the proper amount of moisture in the soil surrounding the roots of the plants to prevent a checking of their growth.

Lucerne commonly receives careless treatment at the hands of western irrigators. When water is available and is not needed for other crops it is usually turned on the lucerne fields or meadows whether these need it or not. There is no question that yields of lucerne might be considerably increased if more care was used in finding out when to apply water. In each kind of soil and under any given set of climatic conditions there is a certain percentage of soil moisture which will give the best results. Under the present unskilful practice it is impossible to maintain uniform soil-moisture conditions for any length of time. The soil is apt to receive too much or too little water, or else it is deluged with cold water at a time when it needs only heat and air. The number of irrigations required depends upon the depth and nature of the soil, the depth of ground water, the number of cuttings, and the rainfall, temperature, and wind movement. Other things being equal, more frequent waterings are required in the warm sections of the South than in the cooler portions of the North. The number of irrigations per year for lucerne ranges from four in Montana and Wyoming to as many as twelve in parts of California and Arizona. In localities where water is scarce during part of the season the number of waterings, as well as the amount used each time, depends on the available supply. It is a common practice to apply frequent and heavy irrigations in spring, when water is abundant, and to water less often and more sparingly when the supply is low.

Winter Irrigation of Lucerne.

When water is applied either to bare soil or to crops outside of the regular irrigation season, it is termed winter irrigation. The practice thus far has been confined largely to the warmer parts of the arid region. It has become well established in Arizona and California, and is being quite rapidly extended to parts of Oregon, Kansas, and the Rocky Mountain States.

Experience has shown that a deep retentive soil is capable of storing a large quantity of water. On account of the fluctuation of western streams of all kinds, from the small creek to the large river, the greatest flow of water often comes at a season when there is least demand for it. In a few localities adequate storage facilities have been provided to retain the surplus, but as a rule it is allowed to go to waste. The passage of so much waste water led to the introduction of winter irrigation, and in nearly every case the results have been satisfactory. The chief differences between winter and ordinary irrigations are the larger volumes used, the crude manner of conveying and applying the water, and the dormant or partially dormant condition of the plants at the time of irrigation.

In Fresno County, Cal., water is turned into the canals in January and February. The large canals of the Modesto and Turlock districts run more than half a head during the latter half of February. This is the rainy period in both these localities, and the soil is usually too wet for plant growth, but water is applied to lucerne fields to fill up the subsoil, so as to provide a surplus for the rainless summer, when water is scarce.

Besides furnishing a supply of much-needed moisture, winter irrigation, when conditions are favourable, prevents winter-killing and improves the mechanical condition of the soil.

Winter-killing of Lucerne.

The winter-killing of lucerne is confined chiefly to the colder and more elevated portions of the Rocky Mountain region and to the northern belt of humid States. Damage from cold is rare in Arizona, and in California it is confined to young plants. In both the Sacramento and San Joaquin valleys of the latter State the seed is frequently sown in midwinter, and the slight frosts which occur occasionally in December and January in both these valleys are severe enough to kill very young plants. The belief is common that the plants are safe after they have put forth their third leaf.

In the colder portions of Montana, Wyoming, Colorado, Utah, and the Dakotas, lucerne is apparently winter-killed from a variety of causes, and sometimes from a combination of causes. The percentage of loss around Greeley, Colo., has been placed at two per cent. per annum. In this locality, and throughout the Cache la Poudre Valley in northern Colorado, most of the winter-killing is done in open, dry winters and is quite generally attributed to a scarcity of moisture in the soil. In the winter of 1907 considerable damage was done to the lucerne fields around Loveland, Colo., on account of the long dry spell in midwinter. The old lucerne fields suffered most. It was the opinion of the farmers that a late fall irrigation would have prevented the loss.

Near Wheatland, Wyo., the higher portions of the fields suffer most damage in winter, and here also the cause is said to be lack of moisture in the soil, combined with the effects produced by cold and wind.

At Choteau, in northern Montana, a farmer watered, late in the fall, part of a lucerne field which was two years old, and it winter-killed, while the unwatered portion escaped injury. This and other evidence along the same line which might be given go far to demonstrate that under some conditions too much moisture is as detrimental as too little.

Probably the chief cause of the winter-killing of lucerne is alternate freezing and thawing. The damage from this cause is greatly increased when any water is left standing on the surface. A blanket of snow is a protection, but when a thin sheet of ice forms over portions of a field the result is usually fatal to plants. The bad effects of alternate freezing and thawing on lucerne may be observed at the edge of a snow bank. This crop is likewise injured by the rupture of the tap roots caused by the heaving of the soil.

From present knowledge of the subject, the means which may be used to protect lucerne fields from winter-killing may be summed up as follows : Where both the soil and the air are dry, the plant should be supplied with sufficient water for evaporation, but the land should be drained so thoroughly that none of the top soil is saturated; a late growth should not be forced by heavy irrigations late in the growing season; if the soil is dry, irrigate after the plants have stopped growing; and the latest growth should be permitted to remain on the ground, unpastured as a protection.

It may be stated in conclusion that the loss to the farmer from the winter-killing of lucerne is not as great as might appear at first. The damage is done in winter, and there is ample time to plough the plants under and secure another crop, which is usually heavy, owing to the amount of fertilisers added by the roots of lucerne. The Montana farmer who increased his average yield of oats from 50 to 103 bushels per acre by ploughing under winter-killed lucerne illustrated this point.

Seeding Lucerne on Land to be Irrigated.

In Utah, the most common practice now is to sow lucerne without a nurse crop. From 12 to 18 lbs. of Utah-grown seed is put in with a 6-inch press drill to a depth of ¾ to 1½ inches during the first half of April. Irri-

gation before seeding is not necessary, as the soil is usually moist and contains sufficient moisture to support the plants until they attain a height of 6 to 10 inches. At this stage the lucerne and the weeds are cut short about 4 inches above the surface, the cutter bar of the mower being raised for that purpose, and the cuttings are left on the ground. Water is kept off after cutting until the crop begins to suffer. It is believed that when young plants lack moisture they will strike their tap-roots deeper into the soil in quest of water, and in this way develop a better root system than they would under frequent and copious irrigations. When lucerne is sown with a nurse crop, oats is preferred. From 10 to 15 lbs. of lucerne seed is sown with 3 pecks to 1 bushel of oats.

In the Upper Snake River Valley, in Idaho, lucerne is usually preceded by a grain crop. The stubble is ploughed 6 to 9 inches deep in the fall, and early in the spring it is double-disked, harrowed, and smoothed. From 8 to 20lbs. of seed is then drilled in 0.75 inch to 1.5 inches deep in rows 6 inches apart. When oats is used as a nurse crop it is seeded first, 80 to 100 lbs. per acre being used. From 8 to 12 lbs. of lucerne seed are then drilled in, in the opposite direction. Some farmers use a combination drill which seeds both at the same time. When no nurse crop is used, the lucerne plants are clipped when they reach a height of 8 to 12 inches. This is necessary to hold the weeds in check and to cause the plants to stool.

In the Yakima Valley, March and April are preferred for seeding lucerne, both on account of the climate and the abundant water supply of that period. The ground is ploughed deep, graded, smoothed, and harrowed. From 10 to 20lbs. of seed are then put in with a broadcast seeder and harrowed lightly. The furrows are then marked off and irrigation begins. The ground is kept moist constantly until the young plants are fairly well established. The use of so much water at the start is due largely to the tendency of the soil to bake if allowed to become dry.

The lucerne growers of Montana are about equally divided in opinion as to the advantages of using a nurse crop. Those who seed grain with lucerne claim that they get more out of the land the first season, while those who are opposed to this practice believe that the injury done to the lucerne plants by the grain crop extends through several years, and that the small gain of the first year is more than offset by the lessened yields of lucerne in subsequent years.

In northern Colorado rotation of crops is practised, and lucerne seed is sown with a nurse crop, usually wheat or barley. The seed is drilled early in the spring with a common force-feed press drill equipped with an auxiliary seed box for lucerne seed, which is scattered broadcast between the grain rows and covered by the disk wheels of the press drill. From 12 to 20 lbs. of lucerne seed are sown. Irrigation before seeding is not practised. There is, as a rule, sufficient rainfall to furnish both crops with moisture until the grain is ready to head out and the lucerne is 4 to 6 inches high, when the field is irrigated.

At Wheatland, Wyo., various methods of seeding lucerne are in use, but the one which gives the best results may be described as follows : Drill in one bushel of barley to the acre; then in a week or ten days crossdrill the field, sowing 12 to 15 lbs. of lucerne, setting the press drill so that the seed will be covered 0.75 inch to 1.5 inches deep.

In Yuma and other valleys of Arizona, October planting is preferred. Frequently in this dry climate the land is irrigated before being seeded. It is cultivated, then seeded and harrowed. In the dry-planting method the seed is sown broadcast on the dry soil, harrowed lightly with a brush drag, and then irrigated. A second irrigation is necessary in about eight days to break the surface crust.

In California the treatment given to lucerne in the first stage of its growth varies somewhat with the locality; in Kern County the seed is sown from December to April, inclusive, with a preference for February and March seeding. If the soil is dry, it is first irrigated. In the Modesto and Turlock districts more or less seeding is done throughout the winter months, but the greater part is seeded in March and April, just before the dry season begins. From 30 to 40 acres can be seeded in a day with a hand-broadcasting machine, if the operator sits in the back of a waggon which is driven over the field. Eighteen pounds of seed to the acre is the average amount sown.

Rise of Ground Water and its Effects on Lucerne.

In their natural state the typical soils of the arid region are characterised by the depth of water and their looseness and dryness. The diversion and use of large quantities of water in irrigation soon change some of the natural conditions. A part of the flow in earthen channels escapes by seepage, and still larger quantities percolate into the subsoil from heavy surface irrigations. The waste water from these and other sources collects in time at the lower levels and raises the ground-water level. This rise is usually noticed first in wells, a permanent rise of five feet in a year being not uncommon.

This rise of the ground water is an advantage, provided the water table does not rise too high. It lessens greatly the cost of sinking wells, less water is needed in irrigation, and it furnishes a reservoir from which water can be pumped to supply other lands.

It is not until the water level encroaches upon the feeding zone of valuable plants that its injurious effects are felt by the farmer. Its near approach to the surface may prove so disastrous that its upward trend should be noted with the greatest care. Perhaps the best means of providing for such observations is the use of test wells, referred to on page 91.

There is some difference of opinion as to what depth below the surface marks the danger line for lucerne. It has been shown by Dr. Loughridge, of the University of California, and by other soil physicists, that water may be withdrawn by capillarity from soils to depths varying from 4 to nearly 5 feet, depending on the character of the soil. This fact has an important bearing on the subject, because when the ground water is brought to the surface and evaporated the salts held in solution are deposited at or near the surface. If these salts contain much sodium sulphate, or even sodium chloride, all of which are usually grouped under the common term alkali, the crust formed by them will in time destroy the lucerne. It may be stated, therefore, that when alkali is present in harmful quantities in the ground water it should not be allowed to rise nearer than 4 feet below the surface.

The percentage of harmful salts in the ground water is usually determined by the chemist of the nearest agricultural experiment station, but when an accurate test cannot be made in the laboratory, the farmer may make a practical test in the following manner, in accordance with a suggestion made by A. T. Sweet, of the Bureau of Soils of this Department :—

Take three pots containing equal amounts of soil and plant the same number of grains of wheat in each. Water each pot with equal quantities of water. In No. 1 apply fresh water, in No. 3 ground water, and in No. 2 an equal amount of each kind. The injury, if any, caused by the ground water will be indicated by the longer time required for the plants to appear above the surface, the smaller number of plants to germinate, and their general appearance.

In soils free from alkali but saturated with water there is not the same necessity for holding the ground water continuously below a so-called danger

line. In parts of Kern County, Cal., the ground water sinks to 8 feet below the surface of lucerne fields in summer, but rises to within 1.5 feet of the surface in winter. There is no indication of root rot, and the plants have retained their full vigour. Numerous cases might be cited to show that the rise of water to within a foot or two of the surface for comparatively short periods of time does little injury to the plants. On the other hand, wherever water stands continuously during the irrigation season within a few feet of the surface, it is pretty certain to kill lucerne in three years or less.

The Injurious Effect of Silt on Lucerne and the Benefits to be Derived from Disking.

The silt-laden waters of the rivers of the South-west during periods of high water in time form a crust over the surface of irrigated lucerne fields. The soil formed by such rivers is naturally impervious, and when a coating of fine sediment is deposited around the plants the effect is injurious, particularly to young plants, which may be killed as a result, notwithstanding the fertilising value of the silt. In irrigating with water carrying much silt, the larger and heavier particles are deposited in the channels which convey the water from the streams, while the finer and lighter particles are carried to the fields. These fine particles cement together and form so hard a crust when dry as to exclude both air and moisture from the soil.

Engineers may in time devise a practical remedy for this evil by building settling basins and storage reservoirs, but at present the tendency of many officers of canal companies is to increase the grade of the channels so as to carry the greater part of the silt to the fields. This does not solve the problem; it merely shifts the burden to the water users. To such, disking the surface at the proper time has proved the most efficient remedy. An effort is made to secure well water or clear ditch water while the lucerne is young, and later to counteract the bad effects of muddy water by the free use of the disk.

Disking lucerne is quite generally practised now throughout the West. It is generally done in the spring, as soon as the ground is hard and firm, and before the growth has started. When a field is disked a second time in the same season it is done when the stubble is short, just after the removal of the crop. The disks should be set nearly straight, so as to stir but not overturn the soil. The spring-tooth harrow is used, also, but its tendency is to tear up the ground too much. Perhaps the best implement for this purpose is the spike disk-harrow or lucerne renovator, as it is sometimes called, in which spiked wheels are substituted for the ordinary concave disks.

Disking not only breaks up the impervious layers formed by muddy water, but it splits the old root crowns, thickens the stand, destroys weeds, checks evaporation, and mixes the dead leaves of previous crops with the top layer of soil.

Pasturing Irrigated Lucerne.

Only a small part of the total acreage in lucerne is pastured throughout any one season, but a large part is pastured during short periods, usually in the fall. Since the plants are easily injured and killed by stock when the ground is wet and soft, stock shoud be kept off for a time after irrigation. On this account it is a good plan to have the pastures fenced in three equal parts, and pasture but one at a time. The inclosures should be alternately pastured, irrigated, and the stand allowed to reach a height of 8 inches or so before stock is turned in again. rather than seed is produced.

Production of Lucerne Seed under Irrigation.

The large area which is seeded to lucerne each year creates a demand for lucerne seed. Good seed is grown now in every irrigated State in the West, and the contention that it cannot be produced successfully under irrgation is unfounded. The use of too much water is doubtless the cause of many failures. Any one of the crops may be saved for seed, but it requires about twice as long to produce a seed crop as it does a hay crop, owing to the extra length of time required for the seed to ripen, and the different crops do not yield equally well. The more general custom is to save the second crop for seed, and where this is done it is recommended that the first crop be irrigated as usual for hay, and that water should be applied very sparingly, if at all, to the seed crop. Where the same amount of water is used as for hay, the growth is rank and rapid, and hay rather than seed is produced.

By Authority: FREDK. WM. SIMPSON, Government Printer, Perth.